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STUDY OF REMOTE MILITARY POWER APPLICATIONS
POLE STATION
ANTARCTICA

FOR

UNITED STATES ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS OFFICE
NEW YORK, NEW YORK

MAY, 1960

(REVISED JULY, 1960)



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OAKLAND • CALIFORNIA

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STUDY OF REMOTE MILITARY POWER APPLICATIONS

POLE STATION

ANTARCTICA

FOR

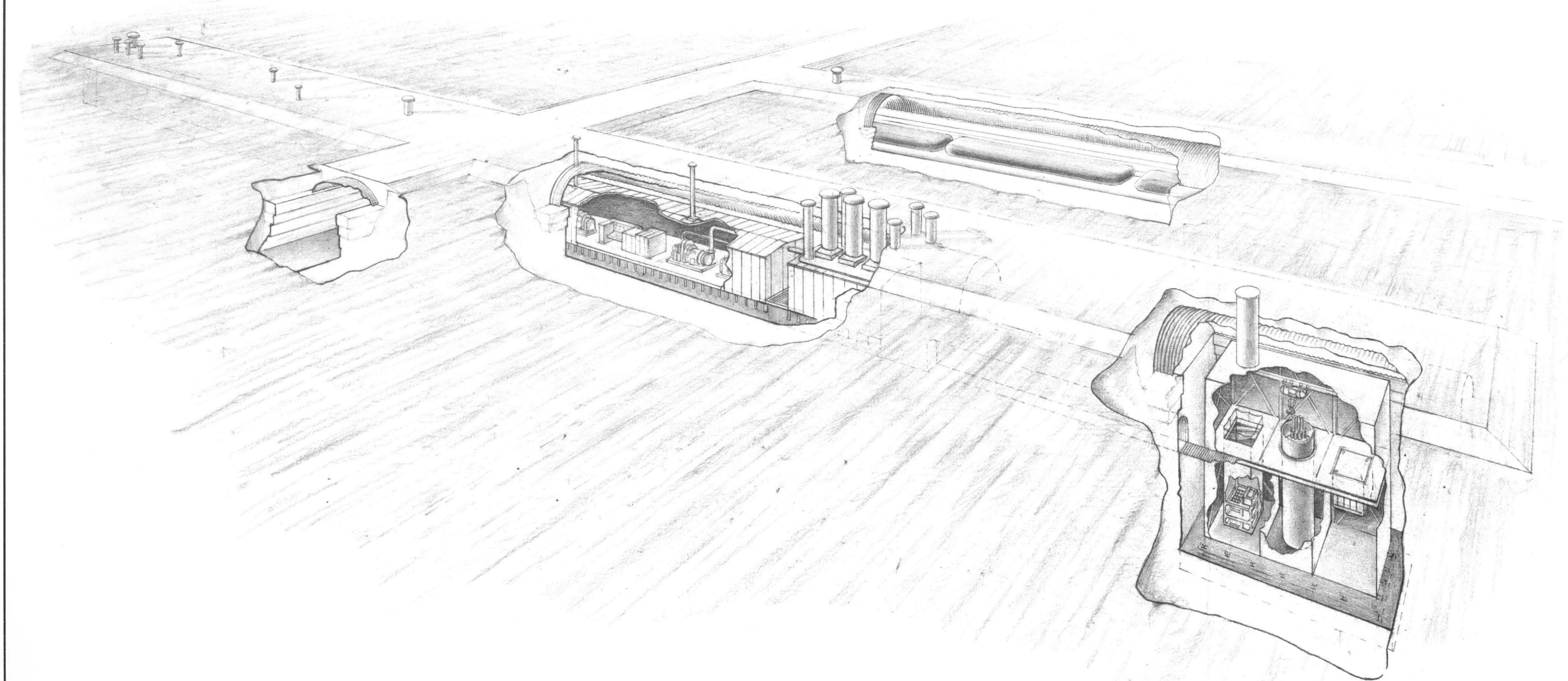
UNITED STATES ATOMIC ENERGY COMMISSION

NEW YORK OPERATIONS OFFICE

NEW YORK, NEW YORK

Contract No. AT (30-1)-2441

May, 1960
(Revised July, 1960)



PROPOSED 500 KW NUCLEAR POWER PLANT
POLE STATION, ANTARCTICA

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SECTION I

INTRODUCTION

On August 17, 1959, the United States Atomic Energy Commission, through the New York Operations Office, issued Contract No. AT (30-1)-2441 to Kaiser Engineers for the "Study of Remote Military Power Applications". The study is essentially an evaluation of the economic considerations of constructing nuclear power plants at Atomic Energy Commission designated military installations, where increased power generating capabilities are contemplated by the Government for the period 1963 through 1970. On February 18, 1960, the scope of the contract was modified to include the study of the economic feasibility of installing nuclear power plants at Byrd and Pole Stations, Antarctica.

This report is an evaluation of the economics involved in constructing and operating a nuclear power plant at Pole Station, Antarctica versus that for a conventional type power plant. Power requirements for Pole Station have been established at 500 kw, of which 200 kw is electric power and 300 kw is heat. Completion of the nuclear power plant is desired by February, 1964.

In the report will be found a description of a proposed 500 kw nuclear power plant together with concept drawings, construction cost estimate, design and construction schedule, and operating, maintenance and fuel costs. For purposes of comparison, a comparable 500 kw diesel power plant was selected, and concepts and costs included.

SECTION II

SUMMARY AND CONCLUSIONS

Pole Station, originally established as one of the United States' scientific stations during the International Geophysical Year in 1956-1957, has been continuously occupied since that time by Navy and scientific personnel. In order to convert the present temporary facilities into a permanent camp, a reliable and economical power source is required to furnish electric power and heat.

Power requirements for the permanent Pole Station have been established by the Navy at 500 kw, of which 200 kw is the electrical load and 300 kw is the heating load. Space heating will be by unit electric heaters. Operation of the power plant is desired by early 1964 (Section III A).

An analysis of the available reactor designs indicates that the PL-2 reactor as designed by Combustion Engineering, Inc. for the Atomic Energy Commission would provide a suitable nuclear power source meeting the requirements for the station. Studies further indicate that a satisfactory nuclear power plant would consist of one PL-2 power plant backed up by three 250 kw diesel engine generators. Sufficient fuel oil would be stored at the station to provide for operation of two of the three 250 kw units at full power for approximately $7\frac{1}{2}$ months. In the event the reactor is down for a period in excess of $7\frac{1}{2}$ months, the amount of fuel oil in storage will be sufficient to operate one diesel engine generator at 200 kw and provide oil for the unit heaters for a total period of 12 months (Section III-B).

For comparison purposes, a conventional power plant consisting of four 250 kw diesel engine generators was selected. Sufficient fuel oil would be stored at the station to provide 14 months' operation at full load of 500 kw (Section III B).

The PL-2 nuclear power plant is a "portable packaged" power plant in the sense that the systems are preassembled and packaged at the point of manufacture to minimize the amount of construction work necessary at the site. The maximum weight of any single package is limited to 15 tons, the load that can be transported by a C-130-B cargo aircraft equipped with skis. The power plant is planned for installation at the Pole in two seasons, November 1962 to February 1963, and November 1963 to February 1964. The construction season is limited each year to the period that aircraft can land and take off at the South Pole (Sections III C and D).

General arrangement and outline drawings have been prepared for both nuclear and conventional power plants to permit the preparation of reasonable and comparable estimates of construction cost. Table 1, page 4, summarizes the project cost estimates and unit power costs for the nuclear and conventional power plants. A summary of the nuclear and conventional power plant data is shown in Table 2, page 5.

The project schedule for the 500 kw nuclear power plant covers a 26-month period from initiation of the project to final completion in early February 1964. The project schedule for the comparable 500 kw conventional power plant covers a 26-month period from initiation of the project to final completion in early February 1964.

Sections IV and V present facility descriptions, cost estimates, construction schedules, and concept drawings for the nuclear and conventional power plants.

TABLE 1

ESTIMATED CONSTRUCTION AND OPERATING COSTS

500 KW (FIRM) NUCLEAR AND CONVENTIONAL POWER PLANTS

Estimated Construction Costs

	<u>Nuclear Power Plant</u>	<u>Conventional Power Plant</u>
Total Construction Cost	\$4,958,000	\$1,875,000
Escalation	302,000	115,000
Total including Escalation	\$5,260,000	\$1,990,000
Design Engineering	400,000	100,000
Total Excluding Contingency	\$5,660,000	\$2,090,000
Contingency	1,140,000	310,000
Total	\$6,800,000	\$2,400,000
 Fuel Oil in Storage	 600,000	 180,000
Total Project Cost	\$7,400,000	\$2,580,000

Estimated Annual and Unit Power Costs

	<u>Nuclear Power Plant</u>		<u>Conventional Power Plant</u>	
	<u>Average</u>	<u>Unit Cost</u>	<u>Average</u>	<u>Unit Cost</u>
	<u>Annual</u>	<u>in mills (4)</u>	<u>Annual</u>	<u>in mills (4)</u>
	<u>Cost</u>	<u>per kwhr</u>	<u>Cost</u>	<u>per kwhr</u>
Fixed Charges (1)	\$370,000	84.5	\$ 129,000	29.5
Operating and Maintenance Cost (2)	215,000	49.1	215,000	49.1
Nuclear Fuel Cost (3)	77,000	17.6		
Fuel Oil Cost (5)	132,000	30.1	1,316,000	300.5
 Total Cost	\$794,000	181.3	\$1,660,000	379.1

NOTE: (1) Based on 20-year plant life equivalent to 5% of the total project cost. No interest on investment has been included.

(2) Excludes interest on cost of fuel oil in storage, interest on spare parts, nuclear indemnity insurance, other insurance and taxes.

(3) Excludes nuclear fuel use charge except during fabrication period.

(4) Unit power cost is based on 100% of firm power requirement equivalent to 4,380,000 net kilowatt hours per year.

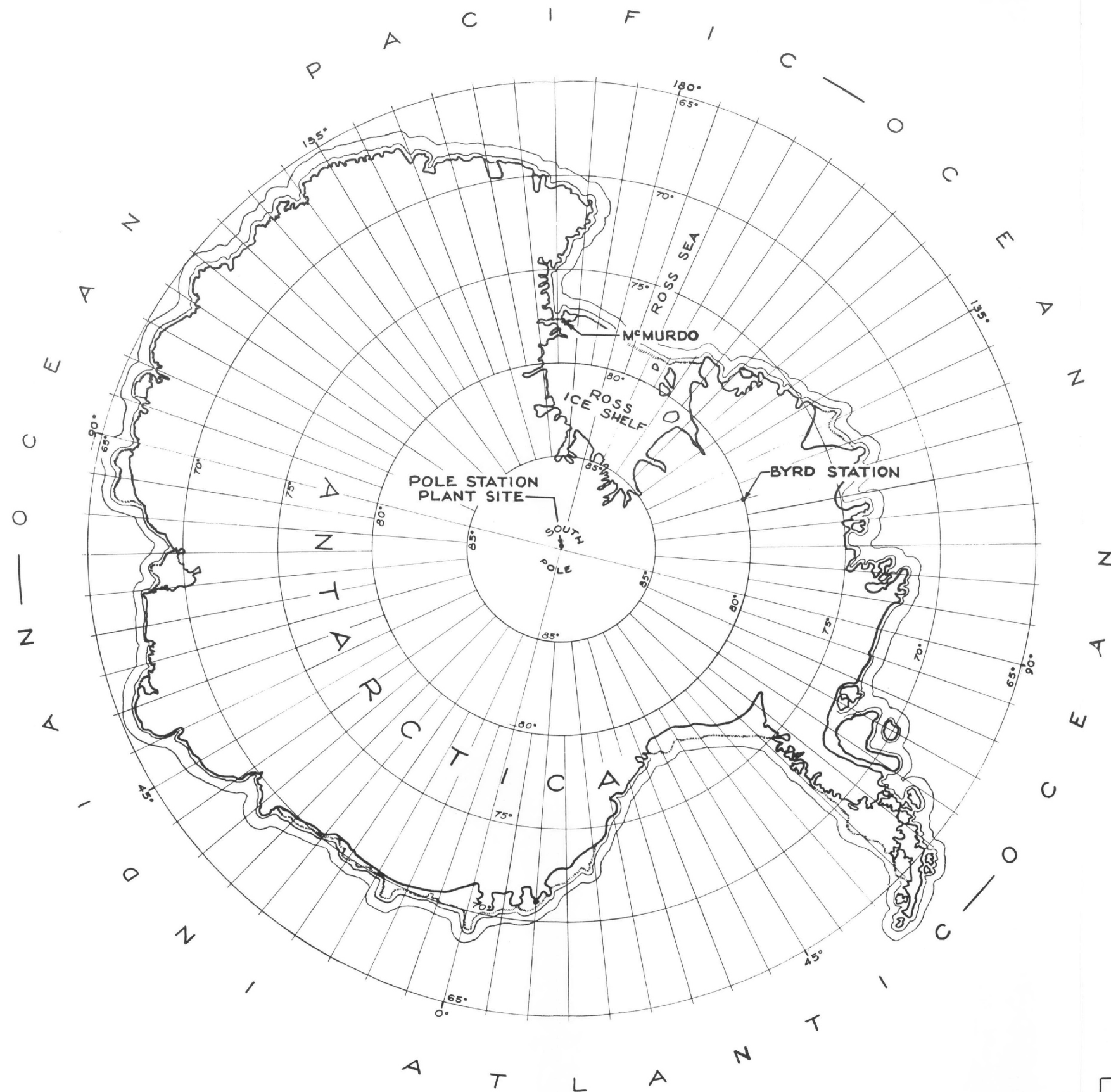
(5) Based on 1960 commercial rates plus shipping costs and average escalation over the life of the plant.

TABLE 2
SUMMARY OF POWER PLANT DATA

	<u>Nuclear Plant</u>	<u>Conventional Plant</u>
<u>1. Over-all Performance</u>		
Type of reactor/conventional power source	Boiling water reactor, PL-2	Diesel engine driven generators
No. of reactors	1	
No. of turbine-generators/diesel engine generators	1	4
Electrical Capability		
Gross	625 kw	1,000 kw
Net	500 kw	500 kw (firm)
Turbine Steam		
Flow	10,300 lb/hr	
Pressure	600 psia	
Temperature	486° F	
Feed-water return temperature	258° F	
<u>2. Reactor Characteristics</u>		
Fuel Assembly		
Fuel material	UO ₂	
Initial enrichment	4.5%	
Weight of fuel in core	69.5 kg (U-235)	
Fuel burnup at discharge	12.4 kg (U-235)	
Cladding material	Stainless steel	
No. of fuel elements	24	
Control Rods		
No. of control rods	9	
Control material	Ag-In-Cd alloy	
Reactor Vessel		
Outside diameter	58 in.	
Over-all height	18 ft	
Material	Carbon steel, stainless clad	
<u>3. Containment</u>	None	
<u>4. Turbine-Generator</u>		
Characteristics:		
Type	Marine type, single barrel, split case, direct connected to generator	

TABLE 2 (Cont'd)

	<u>Nuclear Plant</u>	<u>Conventional Plant</u>
Gross capability (8 in. Hg abs)	625 kw	
Generator coolant	Air	
Generator voltage	480 v, 60 cycle, 3 phase	
5. <u>Condenser</u>		
Number	1	
Type	Air cooled	
6. <u>Stand-by Plant</u>		
Type	Diesel engine generators, heavy duty	
Number	3	
Rating (each)	250 kw	
7. <u>Diesel Engine Generators</u>		
Number	4	4
Type		Low speed, heavy duty
Rating (each)		250 kw
Generator voltage	480	480 v, 60 cycle 3 phase
8. <u>Fuel Oil in Storage</u>		
No. of gallons	217,000	397,000
Months of operation at	7½	14



LOCATION MAP
GRAPHIC SCALE
0 200 400 600 MILES

APPROVAL	DATE
PROJECT ENGINEER	5/5/60
CHIEF ENGINEER	

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DIVISION OF HENRY A. KAMAR COMPANY	
KAISER ENGINEERS OAKLAND CALIFORNIA	
SCALE	DATE
DRAWN BY J. MICHEAL	4-1-60
CHECKED BY A. H. WINKLER	5-2-60
APPROVED BY O. H. MOSELEY	5-4-60
CHIEF DESIGN ENGINEER	5-5-60
JOB No. 5929	DWG. No. 1501-C

SECTION III

GENERAL CONSIDERATIONS

A. Power Requirements

Power requirements for Pole Station include power required for lighting, communications, scientific equipment, small tools, cooling and heating. At the present time the station is heated by oil fired unit heaters located in each building. Cooking is done on oil stoves. Power for lighting, communications, and scientific equipment is supplied by two 60 kw diesel engine generators. With this or similar equipment a complement of 18 men have successfully wintered over at the Station (Ref. 1).

Now that the decision has been reached to man the Pole Station permanently, facilities at the Station must be constructed for a permanent crew capable of operating independently for extended periods. Since the base will be completely isolated from the outside world for periods of up to 10 months, except for radio contact, reliability of the power and heating plants is of prime importance. Also, the ever present danger of fire dictates the use of a heating plant that will minimize this hazard.

Either a nuclear or diesel engine power plant will satisfy the requirements for a reliable, safe and reasonably trouble-free source of energy for power and heat. However, because of the extreme logistic difficulties in supplying the Station, the use of nuclear power does have definite advantages over any other source of power.

The installation of nuclear power generating facilities at Pole Station would permit conversion of Station heating and cooking facilities from oil to electricity. Based on all electric heating, the power requirements have been established by the Navy Department at a total of 500 kw, of which 200 kw is for electric power and 300 kw for heating and cooking. A further requirement is for operation of the proposed power plant by early 1964 (Ref. 2).

B. Proposed Generating Facilities

The selection of components for both the nuclear and conventional power plants is based on the requirement for a reliable source of power. Each of the plants is therefore designed as a multiple unit installation with excess generating capacity and automatic controls and instrumentation.

All power plant schemes contemplate the maximum use of preassembled and prefabricated components to permit the rapid construction of the power plant. The sizes and weights of individual loads will be limited to the capacity of a C-130-B cargo aircraft equipped with skis (Ref. 2). Also see Appendix D.

Selection of the Nuclear Reactor

Four types of reactors were considered for use at Pole Station (Ref. 2). These were:

- PM-1, designed by The Martin Company, Baltimore, Maryland.
- PM-2A, designed by Alco Products, Inc., Schenectady, New York.
- PL-2, designed by Combustion Engineering, Inc., Windsor, Connecticut.
- ML-1, designed by Aerojet-General Nucleonics, San Ramon, California.

The first two are pressurized water reactors, the third is a boiling water reactor and the fourth is a direct cycle gas-cooled reactor-gas turbine power plant. The PM-1, PM-2A and PL-2 are portable power plants in the sense that most of the systems are preassembled into air transportable packages at the point of manufacture to permit erection at a remote site in a short period of time. The ML-1 unit is a mobile power plant; i.e., the entire plant can be moved intact (even after operation) on a large trailer, or shipped by air in two or three plane loads. Table 3, page 14, summarizes the characteristics of these plants.

The PM-2A plant is the most developed at the present time. The first unit is scheduled to be shipped from the factory in May, 1960 for erection at an arctic location shortly thereafter. The net electrical output of the PM-2A power plant is approximately 1,600 kw, and in addition the plant is capable of producing 1,000 lb/hr of steam for space heating. Hence the capacity of this plant is approximately three times that required for Pole Station. The manufacturer estimates that the cost of a PM-2A as described in Table 3 would be \$2,800,000. By eliminating vapor containment, approximately \$50,000 could be saved from this cost. In addition, estimates on similar plants indicate that the cost saving in

scaling down a plant of the PM-2A type designed to meet the 500 kw requirement of the Pole Station is approximately \$100,000 to \$200,000. Thus the cost of a PM-2A type plant with no containment and sized to meet only the power requirements for the South Pole might be expected to cost approximately \$2,600,000, f o b factory, including preassembly and testing (Ref. 3).

Although the PM-1 plant is not presently developed to the same extent as the PM-2A, its design is substantially complete, and since this plant is scheduled for installation at Sundance Air Force Base in Wyoming during the summer of 1961, its cost estimate is on a comparatively firm basis. The designer of this plant has estimated that the selling price of a PM-1 type plant, f o b factory, designed specifically for the South Pole conditions, excluding buildings, containment, and factory preassembly and testing, would be approximately \$1,900,000 (Ref. 4).

The PL-2 plant is somewhat less developed than the PM-1 and PM-2A reactors since only a reference design has been completed at the present time and there are no specific plans for construction of a unit of this type. However, the design of this concept is based upon the experience of the 300 kw SL-1 now operating at the National Reactor Testing Station in Idaho. The PL-2 design differs from the SL-1 in the following respects:

1. The PL-2 is a portable plant whereas the SL-1 is a stationary power plant.
2. The power output of the reference design PL-2 is approximately three times that of the SL-1. It should be noted, however, that for the South Pole Station the power required is only 60% greater than the power output presently achieved in the SL-1.
3. The SL-1 fuel elements use highly enriched uranium and aluminum cladding, whereas the PL-2 fuel elements use partly enriched UO_2 fuel clad with stainless steel.
4. Since the PL-2 is designed to be operable under relatively extreme cold conditions, the air-cooled condensers are a somewhat different design than the SL-1.

It is presently planned that during the summer of 1961 a PL-2 type condenser will be installed at the SL-1 plant in Idaho and the reactor thermal output increased to a level comparable with the reference design PL-2. During the summer of 1961 a partly enriched stainless steel clad core will be installed in the SL-1. Thus by the summer of 1961 the only undemonstrated feature of the PL-2 will be the packaging. The designer of the PL-2 estimates that the cost of a plant of this type, f o b factory, with no containment, excluding buildings and factory preassembly and testing, is approximately \$1,700,000 (Ref. 5).

The first ML-1 unit is scheduled for operation in mid-1961. However, the Gas Cooled Reactor Experiment, which demonstrates some of the features of the reactor portion of the power plant, is presently in operation at the National Reactor Testing Station. Similarly the Gas Turbine Test Facility, in which the gas turbine portion of the plant is being tested, is also presently in operation. Although the nominal rating of the ML-1 is 300 kw, the output is quite sensitive to the ambient temperature, and under the conditions encountered at the South Pole, the plant could easily produce the 500 kw required. The designer of this unit has estimated that an ML-1 plant suitable for erection in Antarctica can be built for approximately \$2,900,000 excluding buildings and factory preassembly and testing. The expected life of the ML-1, however, is only 6 full power years (Ref. 6).

Any one of these four reactors is suitable for use at the South Pole and can be erected in time to meet the required operation date of early 1964. The cost of shipping, housing and erecting the PM-1 and PL-2 plants are nearly equivalent and the PM-2A only slightly more expensive as a result of its greater number of packages. On the other hand, the shipping and erection costs for the ML-1 plant can be expected to be substantially less than for any of the others because of its lighter weight, smaller number of packages, and reduced building and housing requirements.

The estimated annual nuclear fuel cost for the PL-2 is the lowest of the four reactors, with the cost for the PM-1, PM-2A and ML-1 following in that order.

Table 4, page 15, compares total construction costs, annual nuclear fuel costs and annual operation costs for each of these plants. From Table 4 it can be seen that the total project costs of the PM-1, PL-2 and ML-1 plants are quite close, with the construction cost of the PM-2A being in excess of \$1,000,000. Since the ML-1 plant only has an expected life of 6 full power years and the fuel cost is substantially higher than for the other types of plants, the average annual cost for the ML-1 is 2 to 3 times higher than the other plants. For this reason no further consideration was given to using the ML-1 plant for this application.

Similarly the higher annual cost of the PM-2A eliminated this plant from further consideration for this application.

Estimated annual costs for the PM-1 and the PL-2 are within 12% and, within the accuracy of these preliminary estimates, might be considered equal. However, since a selection must be made in order to arrive at a basis for the report, the PL-2 plant was selected as having an apparent saving in annual cost over the PM-1.

Selection of the Nuclear Power Plant

To meet the requirements established by the Navy of 200 kw of electric power and an equivalent of 300 kw of heat, four nuclear power plant schemes were analyzed to determine the most suitable scheme for use at Pole Station, as follows:

1. One 500 kw (net) nuclear power plant and three 250 kw diesel engine generators. Sufficient diesel oil would be stored to operate two of the three diesel engines for 12 months at full load.
2. One 500 kw (net) nuclear power plant and two 200 kw diesel engine generators. Sufficient diesel oil would be stored to operate one of the diesel engines at full load for 12 months and the oil fired unit heaters for 12 months.
3. Two 500 kw (net) nuclear power plants. Sufficient diesel oil would be stored to operate the oil fired unit heaters for 12 months.
4. One 500 kw (net) nuclear power plant and three 250 kw diesel engine generators. Sufficient diesel oil would be stored to operate two of the three diesel engines for approximately $7\frac{1}{2}$ months at full load. This amount of diesel oil would also be sufficient to operate one of the diesel engine generators at 200 kw load and provide oil fired heat for a 12-month period.

Schemes 1 and 4 differ only in the amount of fuel oil storage provided. Table 5, page 16, shows preliminary capital and average annual costs for the four schemes based on estimates received from Combustion Engineering, Inc. for the PL-2 reactor. Scheme 2 has the lowest capital and average annual costs of any of the schemes.

Scheme 2 was not selected because of the need to use the oil fired heaters during emergencies and when the reactor is shut down for normal maintenance and refueling. Besides the fire hazard inherent in using the oil fired heaters, the heaters would have to be left in place at all times and maintained in a ready to operate condition.

Scheme 4 with the next lowest capital and average annual costs was selected as being the most suitable scheme for use at the Pole. During the time the reactor is shut down for routine maintenance and refueling, two of the 250 kw diesel engine generators would be used to produce the full 500 kw required for power and heat. During an emergency shutdown of the reactor, full power could be produced

if the emergency took place any time within $7\frac{1}{2}$ months of the next summer season. At other times full power could be produced long enough to set up and fuel the oil fired heaters and stoves, after which only one diesel engine generator would operate to produce 200 kw of power.

Selection of Conventional Power Plant

Selection of the conventional power plant was based on the same power requirements and criteria used in selecting the nuclear power plant.

The conventional power plant must have the same degree of reliability and ability to deliver power under all operating conditions. For these reasons, the design of the plant must include provisions for excess capacity, quick starting, load sharing, automatic synchronization, and complete instrumentation.

Unit capital costs and production costs for power plants of the size required for the Pole station are considerably higher for gas turbine and conventional steam plants than for diesel engine plants (Ref. 7). Therefore, the conventionally fueled power station selected for this comparison is of the multiple unit diesel engine generator plant design.

The requirement of reliability (continuity) of power service indicates the use of multiple and completely independent generating units, with excess capacity provided in the form of spare units. System simplicity, which is a measure of system reliability, is maximum when the smallest number of machines is used to meet the requirements. Since one unit will be down at planned intervals for maintenance and overhaul, two spare units will be provided in addition to those required to meet normal load requirements.

For comparison purposes two conventional power plant schemes were analyzed to determine the scheme with the lowest over-all cost, as follows:

1. Four 250 kw diesel-engine generators. Sufficient diesel oil would be stored to operate two of the four diesel engines at full load for 14 months.
2. Six 125 kw diesel engine generators. Sufficient diesel oil would be stored to operate four of the six diesel engines at full load for 14 months.

Table 6, page 17, shows preliminary estimated capital and annual costs for the two conventional power plant schemes. Scheme 1, with the lowest annual cost, was selected as the most suitable type conventional power plant for installation at Pole Station. The cost of the initial 1 1/4 month supply of diesel oil is included in the capital cost.

For either scheme, heavy duty, turbo-charged diesel engines, 720 rpm or less and with low BMEP, were selected to reduce maintenance and provide a reliable source of power with minimum fuel consumption.

TABLE 3
SUMMARY OF CHARACTERISTICS
PORTABLE AND MOBILE NUCLEAR POWER PLANTS

<u>CONCEPT</u>	<u>ML-1</u>	<u>PL-2</u>	<u>PM-1</u>	<u>PM-2A</u>
Type of Reactor	gas-cooled	boiling water	press. water	press. water
Design Contractor	Aerojet-General Nucleonics	Combustion Eng.	The Martin Co.	Alco Products
Nominal Capacity	330 kw (net)	1,000 kw (net) + 0.4 mwt steam	1,000 kw (net) + 2.0 mwt steam	1,560 kw (net) + 0.3 mwt steam
Auxiliary Power, kwe	70	237	250	315
Reactor Thermal Rating, mwt	3.4	8.8	9.37	10
Core Lifetime, mwt-years	3.9	30.0	18.7	8.0
Heat Dissipation	gas-to-air	steam-to-air	steam-to-air	steam-to-glycol
Design Ambient Air Temp., °F	100	60	70	arctic conditions
Design Altitude, ft above sea level	0	6,000	6,500	arctic conditions
Plant Lifetime, years	6	20	20	20
No. of Operating Personnel per Reactor	6	7	8	8
No. of Shipping Packages per Reactor (excluding foundations and turbine building)	4	17	17	26
Shipping Weight, lb per Reactor (excluding foundations and turbine building)	120,000	480,000	510,000	710,000
Delivery Time (f o b Plant)	15 mos.	15-18 mos.	14 mos.	15-18 mos.
Status of Project	Prototype, operation scheduled in 1961. Component tests, GCRE and GTTF are now operating.	Ref. Design of PL-2 com- plete. Stationary, 300 kwe prototype (SL-1) now operating. PL-2 type core to be tested at 8-10 mwt starting July 1961.	Design complete. Operation scheduled for summer 1961 at Sundance, Wyoming.	Being installed at Camp Century, Greenland for operation by September 1, 1960.

TABLE 1
COMPARISON OF COSTS
NUCLEAR POWER PLANT COSTS MODIFIED FOR POLE STATION

	<u>ML-1</u>	<u>PL-2</u>	<u>PM-1</u>	<u>PM-2A</u>
Plant Net Capacity, kwe	500	500	500	500
Reactor Thermal Power, mwt	4.2	3.6	3.5	3.5
Electric Energy per Core, kwhr	4.4 x 10 ⁶	33.9 x 10 ⁶	28 x 10 ⁶	11.3 x 10 ⁶
Electric Energy per Year, kwhr (0.9 plant operating factor)	3.93 x 10 ⁶	3.93 x 10 ⁶	3.93 x 10 ⁶	3.93 x 10 ⁶
Core Lifetime, yr	1.1	7.9	6.0	2.9
Core Fabrication Cost	\$ 240,000	\$ 330,000	\$ 250,000	\$ 240,000
<u>ESTIMATE OF PROJECT COST</u>				
Structures and Improvements	\$ 160,000	\$ 315,000	\$ 286,000	\$ 350,000
Nuclear Power Plant Equipment	<u>2,950,000</u>	<u>1,788,000</u>	<u>1,952,000</u>	<u>2,700,000</u>
Total Direct Construction Cost	\$3,110,000	\$2,103,000	\$2,238,000	\$3,050,000
Indirect Cost	<u>1,280,000</u>	<u>1,560,000</u>	<u>1,660,000</u>	<u>2,170,000</u>
Total Direct and Indirect Construction Cost	\$4,390,000	\$3,663,000	\$3,898,000	\$5,220,000
Escalation	<u>260,000</u>	<u>220,000</u>	<u>234,000</u>	<u>300,000</u>
Total Including Escalation	\$4,650,000	\$3,883,000	\$4,132,000	\$5,520,000
Design Engineering	<u>200,000</u>	<u>400,000</u>	<u>400,000</u>	<u>400,000</u>
Total Excluding Contingency	\$4,850,000	\$4,283,000	\$4,532,000	\$5,920,000
Contingency	<u>970,000</u>	<u>857,000</u>	<u>908,000</u>	<u>1,180,000</u>
TOTAL PROJECT COST	\$5,820,000	\$5,140,000	\$5,440,000	\$7,100,000
<u>ANNUAL COSTS</u>				
Nuclear Fuel				
Fabrication	\$ 218,000	\$ 42,000	\$ 41,000	\$ 83,000
Burnup	32,000	17,000	27,000	28,000
Reprocessing	418,000	11,000	32,000	51,000
Transportation	<u>10,000</u>	<u>7,000</u>	<u>5,000</u>	<u>9,000</u>
Sub-Total, Nuclear Fuel	\$ 678,000	\$ 77,000	\$ 105,000	\$ 171,000
Operating and Maintenance				
Labor w/escalation	\$ 142,000	\$ 184,000	\$ 210,000	\$ 210,000
Supplies	<u>46,000</u>	<u>31,000</u>	<u>32,000</u>	<u>42,000</u>
Sub-Total, Operating and Maintenance	\$ 188,000	\$ 215,000	\$ 242,000	\$ 252,000
Fixed Charges	<u>\$ 875,000 *</u>	<u>\$ 257,000</u>	<u>\$ 272,000</u>	<u>\$ 355,000</u>
TOTAL ANNUAL COST	\$1,741,000 *	\$ 549,000	\$ 619,000	\$ 778,000

* Based on a plant life of 6 full power years.

TABLE 5
COST COMPARISON
NUCLEAR POWER PLANT SCHEMES

<u>Description</u>	<u>Scheme 1</u>	<u>Scheme 2</u>	<u>Scheme 3</u>	<u>Scheme 4</u>
	1-500 kw PL-2 3-250 kw <u>Diesel Generators</u>	1-500 kw PL-2 2-200 kw <u>Diesel Generators</u>	2-500 kw PL-2	1-500 kw PL-2 3-250 kw <u>Diesel Generators</u>
1.0 Land and Land Rights	\$ - -	\$ - -	\$ - -	\$ - -
2.0 Structures and Improvements	457,000	416,000	557,000	457,000
3.0 Reactor Plant	1,131,000	1,131,000	2,024,000	1,131,000
4.0 Turbine-Generator Plant	302,000	302,000	527,000	302,000
5.0 Accessory Electrical Equipment	281,000	281,000	476,000	281,000
6.0 Miscellaneous Power Plant Equipment	61,000	61,000	93,000	61,000
7.0 Transmission Plant	7,000	7,000	7,000	7,000
8.0 Communication System	6,000	6,000	6,000	6,000
9.0 Stand-by Diesel Plant	230,000	116,000	- -	230,000
10.0 Fuel Oil Storage and Distribution System	<u>156,000</u>	<u>100,000</u>	<u>- -</u>	<u>100,000</u>
Total Direct Construction Cost	\$ 2,631,000	\$ 2,420,000	\$ 3,690,000	\$ 2,575,000
11.0 Indirect Cost	<u>2,389,000</u>	<u>2,380,000</u>	<u>2,810,000</u>	<u>2,383,000</u>
Total Construction Cost	\$ 5,020,000	\$ 4,800,000	\$ 6,500,000	\$ 4,958,000
12.0 Escalation 6%	<u>300,000</u>	<u>290,000</u>	<u>390,000</u>	<u>302,000</u>
Total Including Escalation	\$ 5,320,000	\$ 5,090,000	\$ 6,890,000	\$ 5,260,000
13.0 Design Engineering	<u>400,000</u>	<u>400,000</u>	<u>400,000</u>	<u>400,000</u>
Total Excluding Contingency	\$ 5,720,000	\$ 5,490,000	\$ 7,290,000	\$ 5,660,000
14.0 Contingency 20%	<u>1,145,000</u>	<u>1,100,000</u>	<u>1,460,000</u>	<u>1,140,000</u>
Total Including Contingency	\$ 6,865,000	\$ 6,590,000	\$ 8,750,000	\$ 6,800,000
Fuel Oil in Storage *	<u>985,000</u>	<u>630,000</u>	<u>260,000</u>	<u>600,000</u>
TOTAL PROJECT COST	\$ 7,850,000	\$ 7,220,000	\$ 9,010,000	\$ 7,400,000
ANNUAL COSTS				
Nuclear Fuel	\$ 77,000	\$ 77,000	\$ 86,000	\$ 77,000
Diesel Fuel	132,000	84,000	- -	132,000
Operating and Maintenance	<u>215,000</u>	<u>215,000</u>	<u>268,000</u>	<u>215,000</u>
Sub-Total	\$ 424,000	\$ 376,000	\$ 354,000	\$ 424,000
Fixed Charges	<u>393,000</u>	<u>361,000</u>	<u>451,000</u>	<u>370,000</u>
TOTAL ANNUAL COST	\$ 817,000	\$ 737,000	\$ 805,000	\$ 794,000
Quantity Fuel Oil in Storage, Gal	340,000	217,000	81,000	217,000

* The only difference between Schemes 1 and 4 is in the quantities of fuel oil in storage. The value shown for fuel oil in storage is equivalent to the total value of the fuel used annually by the stand-by plant for scheduled shutdowns and refueling (estimated to be 10% of the time).

TABLE 6
COST COMPARISON
CONVENTIONAL POWER PLANT SCHEMES

<u>Description</u>	<u>Scheme 1</u> 4-250 kw Diesel-Engine Generators	<u>Scheme 2</u> 6-125 kw Diesel Engine Generators
1.0 Land and Land Rights	\$ - -	\$ - -
2.0 Structures and Improvements	167,000	203,000
3.0 Fuel Oil Storage and Distribution System	173,000	173,000
4.0 Diesel Generator Plant	243,000	291,000
5.0 Accessory Electrical Equipment	85,000	102,000
6.0 Miscellaneous Power Plant Equipment	16,000	19,000
7.0 Transmission Plant	4,000	5,000
8.0 Communication System	4,000	4,000
Total Direct Construction Cost	\$ 692,000	\$ 797,000
9.0 Indirect Cost	1,183,000	1,363,000
Total Construction Cost	\$1,875,000	\$2,160,000
10.0 Escalation	115,000	130,000
Total Including Escalation	\$1,990,000	\$2,290,000
11.0 Design Engineering	100,000	100,000
Total Estimated Cost Excluding Contingency	\$2,090,000	\$2,390,000
12.0 Contingency	310,000	360,000
Total Including Contingency	\$2,400,000	\$2,750,000
13.0 Fuel Oil in Storage	180,000	180,000
TOTAL PROJECT COST	\$2,580,000	\$2,930,000
ANNUAL COSTS		
Diesel Fuel	\$1,316,000	\$1,316,000
Operation and Maintenance	215,000	220,000
Sub-Total	\$1,531,000	\$1,536,000
Fixed Charges	129,000	146,000
TOTAL ANNUAL COST	\$1,660,000	\$1,682,000

C. Description of Station

Pole Station was established in the winter of 1956-1957 as one of the United States' scientific stations for the International Geophysical Year. The station, the first ever established at the geographical South Pole, is operated jointly by the U. S. Navy and The National Academy of Sciences. As originally constructed the base consisted of two barracks buildings, science building, mess hall, garage and powerhouse, emergency shelter, and shelters for scientific apparatus, all interconnected by covered passageways (Ref. 8).

During the IGY the base was continuously occupied by 9 Navy personnel and 9 scientists. Although individuals are rotated each year, the total number of men "wintering over" has remained more or less constant at 18 (Ref. 1).

Power for the base is presently furnished by two 60 kw diesel generators, using Arctic grade diesel oil. Heat is furnished by oil fired unit heaters. Cooking is done on oil fired stoves. Fuel oil storage is provided by a central system utilizing fuel oil drums located in the covered passageways and caches. Portable pumps are used to pump the oil from the drums to the individual day tanks (Ref. 1).

Fresh water is obtained by melting snow. Sanitary and kitchen wastes are collected and disposed of in selected areas outside the camp.

The area at the Pole is a plateau some 9,200 feet above sea level. Seismic tests conducted during the IGY indicate that the ice cap at the Pole is approximately 8,300 feet thick (Ref. 8).

Mean average temperatures at the Pole range from a low of -79.5° F to a high of -20.2° F. During Deep Freeze IV, October 1958 to September 1959, the lowest recorded temperature was -110° F in September 1959. The maximum temperature was -6° F in December 1958. The average wind velocity is about 14 mph. However, wind velocities as high as 45 mph have been recorded. Snowfall averages about 6 in. per year (Ref. 1).

For six months of the year the sun is below the horizon, and for at least four of the six months artificial light is required to move about outdoors (Ref. 8).

Transportation to the station will be by means of ski equipped C-130-B cargo aircraft flying from the Naval Air Facility at McMurdo Sound some 850 miles distant. Weather conditions at the Pole limit the flying season to about three months per year, from about November 15 to February 10. Aircraft land at the Pole on a runway prepared by leveling the snow ridges by means of a drag (Ref.2).

The C-130-B cargo aircraft, flying between McMurdo Sound and the Pole, can carry a maximum pay load of 30,200 lb to the Pole Station based on an empty return run. If a pay load is to be carried on the return flight from the Pole, the initial pay load from McMurdo must be reduced to compensate for the additional fuel required. The maximum package size that can be carried in a C-130-B aircraft is 109 in. high by 120 in. wide by 481 in. long (Appendix D).

The normal method of transportation from the United States will be by cargo vessel to McMurdo Sound and then by C-130-B to the South Pole. Ships assisted by icebreakers can enter McMurdo Sound starting the latter part of December. Cargo is off-loaded onto the ice and hauled by tractor drawn sleds to NAF, McMurdo, four to ten miles distant. In the past the last ship has left the area about the middle of March (Ref. 1).

Cargo planes flying from New Zealand 2,300 miles distant can operate into NAF McMurdo starting in October and continuing until the middle of February (Ref. 1).

The proposed power plants can be located above the snow or in cut-and-cover tunnels under the snow, as is being done at Camp Century in Greenland. Although the snow buildup is not a major problem as it is in Greenland, the advantages of a controlled environment in reducing heat losses from the buildings and in reducing maintenance costs outweigh the additional cost of constructing the plants in tunnels in the snow. The temperature of the snow a few feet under the surface remains a fairly constant -60° F throughout the year. This contrasts with outside temperatures ranging from -6° F to -110° F. Also, the absence of wind should serve to greatly reduce heat losses from the buildings. Further, there is no need to shovel snow by hand away from the buildings, as now appears necessary even during some of the coldest days. The advantages of locating not only the power plants but also the entire permanent base in tunnels under the snow are such that the Navy is now making plans for such an installation at Byrd Station. Therefore it is proposed to locate both the nuclear and conventional power plants in cut-and-cover tunnels (Ref. 9).

By careful design of the tunnels and foundations, minimum maintenance is contemplated.

D. Construction Considerations

Construction at Pole Station imposes many new and unusual problems in logistics and working conditions. Unless personnel are prepared to winter over, the construction season is limited to approximately 60 days from early December to early February, during which time the sun is visible 24 hours per day and weather conditions are the most favorable.

Living accommodations at Pole Station are limited, as are messing and other facilities. Since construction work will be done on a two-shift per day basis, personnel can be doubled-up in existing quarters so only a limited amount of temporary quarters will be required. However, additional messing facilities will have to be provided. A wintering-over construction force could not be accommodated without extensive new construction and the importation of large amounts of fuel oil and other supplies.

By careful planning it is anticipated that the nuclear or conventional power plant can be completed in two seasons, and therefore a wintering-over party will not be required.

Adequate quarters and other facilities are available at NAF McMurdo for construction personnel required to construct the permanent fuel oil tanks and to support the construction work at the site.

Construction Labor

All construction work will be performed by Navy Construction Battalion personnel with the assistance of contractor supervisory personnel. In the past work has been performed on a 12-hour per day shift, seven days a week. For purposes of this study a six day work week has been adopted with two 10-hour shifts per day. Construction labor costs have been based on an average rate of \$20,350 per man year of which \$7,500 is pay and allowances and the balance transportation, services and supplies (Ref. 10).

Approximately 85 Construction Battalion personnel would be required the first season to complete the snow tunnels, foundations and buildings for the nuclear power plant. The following season approximately 88 Construction Battalion and contractor personnel would unload and erect the power plant equipment.

The second season the nuclear power plant operators will assist the construction personnel in the final assembly and test of the plant. Also a representative of the nuclear reactor manufacturer will be on hand to lend further assistance, and if necessary winter-over the first year of operation. With proper selection and training of the nuclear power plant operators, it may not be necessary for the manufacturer's representative to winter-over.

Construction Materials

Due to the limited construction season it is imperative that the bulk of the construction materials be prefabricated into units of a size that can be easily handled at the site. Foundation timbers should be precut, predrilled and match marked. Buildings should be constructed of prefabricated panels, using special fasteners similar to the standard T-5 type building. Tunnel arches should be fabricated to size. Fuel oil storage tanks will be made of neoprene coated fabric. Large size piping should be prefabricated with flange connections, etc.

The cost of construction materials has been based on U. S. prices, f a s Davisville, Rhode Island, the supply point for Task Force 43.

Construction Equipment

At the present time one D-2 dozer and one D-2 tractor are on the site. Undoubtedly these will be available a portion of the time to assist in unloading aircraft and hauling cargo to the site (Ref. 1).

For construction purposes two additional tractors will be required, one equipped with a dozer and one equipped with an "A" frame hoist. These tractors preferably should be of the D-6 size.

One Peter Snow Miller will be required for excavating the tunnels and backfilling over the tunnel arches.

Other equipment required will include cargo sleds, welding machines, and miscellaneous small tools.

At the end of each construction season the tractors and Snow Miller will be returned to McMurdo Sound for maintenance and storage.

Permanent Equipment

All permanent power plant equipment will be purchased in the United States. The nuclear power plant will be designed so all major items will be preassembled at the factory into packages that can be easily installed in the field.

Shipping and Warehousing

The key to the successful construction of a power plant at the Pole is the planning and coordination of the shipment of men, materials and equipment. This must of necessity be done in two steps. First, materials and equipment must be assembled at Davisville, Rhode Island, or other selected ports, and shipped by cargo

vessel to McMurdo Sound arriving as early as possible in December. There the materials and equipment will be off-loaded over the ice and stored on shore. A minimum of two C-130-B cargo aircraft will then be used to transport the cargo to the Pole, each plane making an average of one trip per day.

The first year it will be advisable to ship the Snow Miller and the tractors to New Zealand by cargo vessel in November for transshipment in the two C-130-B aircraft that will be used for the Pole flights. This will allow work on the tunnels to begin prior to the arrival of the first cargo vessel at McMurdo Sound.

Personnel and small tools will also be flown into McMurdo Sound before the arrival of the first vessel.

The second year essential equipment needed to start construction will be flown to McMurdo Sound prior to the start of the construction season and then to the Pole. The balance of the materials and equipment will be carried on cargo vessels into McMurdo Sound and then by plane to the Pole. See Tables 7 and 8 on the following pages for logistic data for the nuclear and conventional power plants.

For shipping purposes, all bulk materials will be palletized, with the size and weight of any package limited by the cargo-carrying capacity of the C-130-B.

Contractor Facilities

Personnel furnished by the nuclear manufacturer or other contractor will be limited to a maximum of three at the Pole. Cost of transporting and messing these men is included in the cost estimate.

TABLE 7
POLE NUCLEAR PLANT
LOGISTIC DATA

1962	ITEM	EXPORT WEIGHT ESTIMATED SHORT TONS	NUMBER OF SHIPPING PACKAGES	STAGING AREA	DEPARTURE DATE	METHOD OF SHIPPING	TRANSSHIPPING AREA	NO. OF AIRCRAFT TRIPS	REMARKS
	<u>2.0 Structures and Improvements</u>								
	2.1.2 Tunnel Roof - "Wonder" Arch	100	34 - 3 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	7	Two aircraft required during 1962.
	2.1.3 Meter Supply			Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.4 Sanitary Sewage Disposal	12	4	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	2.1.5 Tunnel Lighting			Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.6 Fire Extinguishing Equipment			Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	112 Tons	38 Packages					8 Trips	
	<u>2.2 Turbine-Generator Building</u>								
	2.2.1 Substructure (Timber 20'-0" Lengths)	38	8	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	}
	2.2.2 Superstructure T-5 Building	50	10 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	4	
	2.2.3 Heating and Ventilating	6	3	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	
	2.2.4 Plumbing	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	2.2.5 Building Electrical	3	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	2.2.6 Painting	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.7 Cranes and Hoists	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	102 Tons	25 Packages					8 Trips	
	<u>2.3 Reactor Building</u>								
	2.3.1 Substructure	50	10 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	4	
	2.3.2 Superstructure	45	9 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	
	2.3.3 Miscellaneous	10	2 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	1	
	Sub-Total	105 Tons	20 Packages					8 Trips	
	<u>2.4 Diesel Generator Stand-by Building</u>								
	2.4.1 Substructure	40	8 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	}
	2.4.2 Superstructure	35	7 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	
	2.4.3 Miscellaneous	50	2 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	
	Sub-Total	155 Tons	17 Packages					6 Trips	50 Tons - Tankage installed at McMurdo
	<u>Construction Equipment and Supplies</u>								
	Snow Miller	15	1	Davisville, Rhode Island	September	AKA to New Zealand, and Pole	New Zealand		5 Trips from New Zealand to McMurdo 5 Trips from McMurdo to Pole 3 Trips return from Pole (Snow Miller and tractors returned for overhaul to McMurdo at end of construction season)
	Tractors	17	2	Davisville, Rhode Island	September		New Zealand		
	Welding Machines	9	2	Davisville, Rhode Island	September		New Zealand		
	Miscellaneous	40	6 - 5 Ton Packages	Davisville, Rhode Island	September		New Zealand		
	Sub-Total	80 Tons	13 Packages					13 Trips	
	TOTAL 1962	554 Tons	113 Packages					43 Trips	
	<u>Personnel</u>								
	Navy (McMurdo) 20								Naval Construction Personnel will be flown from COMUS to Antarctica on cargo airlift aircraft. Personnel will be required at McMurdo for tank erection, equipment off-loading, loading on aircraft and warehousing.
	Navy (Pole) 65								
	Total 85								
1963									
	<u>3.0 Reactor Plant (PL-2)</u>								
	3.1 Reactor Package	60	4 - 15 Ton Packages	Davisville, Rhode Island	September	AKA cargo vessel to New Zealand. PL-2 plant to be airlifted to McMurdo.	New Zealand	4	Two C-130-B aircraft required during 1963.
	3.2 Feed and Condensate Package	15	1	Davisville, Rhode Island	September		New Zealand	1	
	3.3 Waste and Spent Fuel Storage	15	1	Davisville, Rhode Island	September		New Zealand	1	
	3.4 Purification Package	15	1	Davisville, Rhode Island	September		New Zealand	1	
	3.5 Miscellaneous Equipment	10	1	Davisville, Rhode Island	September		New Zealand	1	
	3.6 Piping and Insulation	15	1	Davisville, Rhode Island	September		New Zealand	1	
	Sub-Total	130 Tons	9 Packages					9 Trips	
	<u>4.0 Turbine-Generator Plant</u>								
	4.1 Turbine-Generator Package	15	1	Davisville, Rhode Island	September	AKA cargo vessel to New Zealand. PL-2 plant to be airlifted to McMurdo.	New Zealand	1	
	4.2 Condenser Package	30	2	Davisville, Rhode Island	September		New Zealand	2	
	4.3 Piping	10	1	Davisville, Rhode Island	September		New Zealand	1	
	Sub-Total	55 Tons	4 Packages					4 Trips	
	<u>5.0 Accessory Electrical Equipment</u>								
	5.1 Electrical Package	15	1	Davisville, Rhode Island	September	AKA cargo vessel to New Zealand. PL-2 plant to be airlifted to McMurdo.	New Zealand	1	
	5.2 Switchgear and Miscellaneous	8	1	Davisville, Rhode Island	September		New Zealand	1	
	Sub-Total	23 Tons	2 Packages					2 Trips	
	<u>6.0 Miscellaneous Power Plant Equipment</u>								
	6.1 Fire Extinguishing Equipment	3	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	2 Trips
	6.2 Fire Alarm System	1	1	Davisville, Rhode Island	September		McMurdo		
	6.3 Shop Equipment	3	1	Davisville, Rhode Island	September		McMurdo		
	6.4 Office Furniture and Equipment	2	1	Davisville, Rhode Island	September		McMurdo		
	6.5 Start-up and Emergency Heating System	10	1	Davisville, Rhode Island	September		McMurdo		
	6.6 Laboratory Equipment	5	1	Davisville, Rhode Island	September		McMurdo		
	Sub-Total	24 Tons	6 Packages						
	<u>9.0 Stand-by Diesel Plant</u>								
	9.1 Engine Generators	45	3	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	3	
	9.2 Switchgear	15	1	Davisville, Rhode Island	September		McMurdo	1	
	9.3 Miscellaneous	15	1	Davisville, Rhode Island	September		McMurdo	1	
	Sub-Total	75 Tons	5 Packages					5 Trips	
	<u>Construction Equipment and Supplies</u>								
	Snow Miller	15	1	McMurdo	September	C-130-B	New Zealand and McMurdo	}	6 Trips
	Tractors	17	2	McMurdo	September	C-130-B			
	Welding Machines	9	2	McMurdo	September	C-130-B			
	Miscellaneous	40	6	Davisville, Rhode Island	September	AKA to New Zealand. Airlift to McMurdo.			
	Sub-Total	72 Tons	6 Packages						
	Sub-Total Less Oil	379 Tons	33 Packages					28 Trips	
	Initial Complement of Oil 217,000 Gallons	770 Tons	Bulk	Norfolk, Virginia	September	AOG Tanker to McMurdo	McMurdo	55 Trips	
	TOTAL 1963	1,149 Tons	33 Packages					83 Trips	
	<u>Personnel</u>								
	Navy (McMurdo) 20								Naval Construction Personnel will be flown from COMUS to Antarctica on cargo airlift aircraft. Personnel will be required at McMurdo for tank erection, equipment off-loading, loading on aircraft and warehousing.
	Navy (Pole) 65								
	Civilian (Pole) 3								
	Total 88								

TABLE 8
POLE CONVENTIONAL PLANT
LOGISTIC DATA

1962	ITEM	EXPORT WEIGHT ESTIMATED SHORT TONS	NUMBER OF SHIPPING PACKAGES	STAGING AREA	DEPARTURE DATE	METHOD OF SHIPPING	TRANSSHIPPING AREA	NO. OF AIRCRAFT TRIPS	REMARKS
	2.1 <u>General Improvements</u>								
	2.1.2 Tunnel Roof	75	15 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	5	1. During 1962 one C-130-B aircraft will be required to transport men and materials from CONUS to Pole Station. See Appendix A for particulars of the C-130-B.
	2.1.3 "Wonder" Arches	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	
	2.1.4 Water Supply System	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.5 Sanitary Sewage Disposal	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.6 Tunnel Lighting	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.1.6 Fire Extinguishing Equipment	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	6 Trips	
	Sub-Total	80 Tons	19 Packages						
	2.2 <u>Diesel Generator Building</u>								
	2.2.1 Substructure Timber	54	13 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	7 Trips
	20'-0" Lengths - Cut and Marked								
	2.2.2 Superstructure	48	16 - 3 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Roof Panels, Trusses, Wall and Floor Panels (T-5 Building)								
	Sub-Total	102 Tons	29 Packages						
	3.0 <u>Oil Storage</u>								
	Tankage at Pole	8	8	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	2 Trips
	8 Neoprene Tanks 50,000 Gallons Each	7	32	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Lube Oil								
	32 - 55 Gallon Drums	6	2	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Piping and Pumps	115	23 - 5 Ton Packages	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Tankage at McMurdo	5	3	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		Install at McMurdo
	Tote Tanks and Transfer Equipment						Off-load at McMurdo		Hold at McMurdo
	Sub-Total	141 Tons	68 Packages						
	<u>Construction Equipment and Supplies</u>								
	Snow Miller	15	1	Davisville, Rhode Island	September	AKA to New Zealand, via Aircraft from New Zealand to McMurdo	New Zealand and McMurdo	4 Trips	Snow Miller and Tractors to be returned to McMurdo for overhaul and repairs and reshipped by air the following year to Pole Station
	Tractors	17	2 - 8.5 Tons Each	Davisville, Rhode Island	September				
	Cargo Sheds	3	1	Davisville, Rhode Island	September				
	Welding Equipment	8	2 - 4 Tons Each	Davisville, Rhode Island	September				
	Miscellaneous Supplies	15	1	Davisville, Rhode Island	September				
	Sub-Total	58 Tons	7 Packages						
	TOTAL 1962	381 Tons	124 Packages					19 Trips	
	<u>Personnel - Navy</u>			Davisville, Rhode Island	November 1st			1 Trip	Naval Construction Personnel will be flown from CONUS to Antarctica on cargo airlift aircraft. Personnel will be required at McMurdo for tank erection, equipment off-loading and loading on aircraft and warehousing.
	Pole 20								
	McMurdo 8								
	Total 28								
1963									
	<u>Construction Equipment and Supplies</u>	52	3	McMurdo (Stored)	November	C-130-B	McMurdo	4	1. During 1963 three C-130-B aircraft will be required to transport men and materials from CONUS to the Pole. 2. The 177 tons of material and equipment required for the plant will become a portion of consolidated shipment on an AKA (6,000 ton) and costs have been prorated in the report on the assumption that the balance of cargo will be required for the existing stations.
	2.2 <u>Diesel Generator Building</u>								
	2.2.3 Heating and Ventilation	4	4	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	1
	Equipment and Ductwork	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.3 Plumbing	1	2	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.5 Building Electrical	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.6 Miscellaneous Cranes and Hoists	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	2.2.7 Paint	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	61 Tons	12 Packages					5 Trips	
	4.0 <u>Diesel Generator Plant</u>								
	4.1 Diesel Generators	60	8 (2 Packages Per Engine)	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	4
	4.2 Combustion Air	3	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.3 Cooling System	2	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.4 Foundations Timber	4	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.5 Lubricating System	4	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.6 Instrumentation	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.7 Piping (20'-0" Lengths)	8	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.8 Starting Air	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	4.9 Auxiliary Foundations	3	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	86 Tons	16 Packages					6 Trips	
	5.0 <u>Accessory Electrical Equipment</u>	20	3	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	}	2 Trips
	Switchgear, Panels, Cables, Breakers, Etc.								
	6.0 <u>Miscellaneous Power Plant Equipment</u>	8	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	28 Tons	4 Packages						
	7.0 <u>Transmission Plant</u>	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo	(Consolidated with Item 4.0)	
	8.0 <u>Communication Equipment</u>	1	1	Davisville, Rhode Island	September	AKA to McMurdo	McMurdo		
	Sub-Total	2 Tons	2 Packages						
	Sub-Total Less Oil	177 Tons	34 Packages					13 Trips	
	Initial Complement of Oil 397,000 Gallons	1,410 Tons	Bulk	Norfolk, Virginia	September	AOG Tanker to McMurdo	McMurdo	100 Trips	14 months' supply of fuel will be pumped into storage tanks at McMurdo and transhipped in 4,000 gallon tote tanks via C-130-B aircraft.
	TOTAL 1963	1,587 Tons	34 Packages					113 Trips	
	<u>Personnel - Navy</u>							1 Trip	Naval Construction Personnel will be flown from CONUS to Antarctica on cargo airlift aircraft.
	Pole 25								
	McMurdo 10								
	Total 35								

SECTION IV

PROPOSED NUCLEAR POWER PLANT

A. General Description

The nuclear power plant for the Pole Station will consist of a modified PL-2 reactor plant and a stand-by diesel plant. The PL-2 reactor plant generator will be modified to produce 500 kw net electrical power at 480 volts. The stand-by diesel plant will consist of three 250 kw diesel generators to provide 100% back-up for the reactor plant during shutdowns for maintenance and refueling.

The reactor plant is based on the PL-2 design being made by Combustion Engineering, Inc. under contract to the United States AEC. The plant is described in References 11, 12 and 13 and includes design changes made up to April 23, 1960. The estimate of cost is based on cost data furnished by Combustion Engineering, Inc. (Ref. 5). The PL-2 reactor is a light-water moderated and cooled, natural circulation boiling water reactor capable of producing 8.5 megawatts of thermal power in a stainless steel clad uranium dioxide pellet core, enriched to 4.5% U-235 content. The core will be contained in a stainless steel clad, carbon steel cylindrical pressure vessel, 52 in. by 18 ft high. The top head will contain penetrations for nine rack-and-pinion control rod drives. The control rods will be cruciforms of silver-indium-cadmium alloy jacketed in stainless steel. The reactor pressure will be automatically controlled by the central control rod. The reactor will produce 11,730 lb/hr of dry saturated steam at 615 psia with feed water at approximately 258° F. By-pass demineralizer purification systems will be used to maintain system purity, and storage tanks will be provided to collect and store radioactive waste from all of the plant drains and sumps. The reactor vessel will be contained in a 11.5 ft cylindrical, water filled shield tank. The waste storage tank and spent fuel storage tank will be located adjacent to the shield tank.

Reactor produced steam will be fed to the turbines by a 3 in. stainless steel pipe. About 1,000 lb/hr of steam from the reactor will be by-passed to a space heat exchanger, which will produce hot water for building heating. The turbine exhausts through a 12 in. stainless steel pipe to one air cooled condenser operating at 8 in. Hg abs. The condenser drains to a hotwell located on the feed and condensate skid.

Make-up water (50 gal per day) is admitted at the hot well. The condensate is used to provide equipment cooling (including shield water cooling) before being returned to the reactor by the feed-water pump.

All plant facilities will be constructed within snow tunnels excavated below the surface. The nuclear plant will be constructed in a tunnel separate from the stand-by diesel plant tunnel and on the opposite side of the station main access tunnel. The nuclear plant tunnel will be 28 ft wide and approximately 300 ft long. The reactor, shield tank, waste tank and spent fuel tank will be located in a portion of the tunnel 49 ft deep. The remainder of the equipment will be located in a tunnel 24 ft deep. There will be 40 ft of snow fill between the reactor and secondary plant to serve as shielding. A small connecting access and pipe tunnel will be provided through the shielding.

The stand-by diesel plant tunnel will be 24 ft wide and 24 ft deep by 200 ft long.

The tunnels will have a short 12 ft wide connecting passageway to the main base access tunnel.

A Peter Snow Miller will be used to excavate the trenches to the required sizes and to prepare level benches for supporting the roof arches spanning the tunnels. After erecting the steel arches, the Miller will be used to place the snow shielding and about 3 ft of snow fill over the tunnels. Clearance between the buildings and the tunnel walls will be provided to permit air circulation and tunnel maintenance.

Buildings and equipment will be supported by timber posts and cribbing bearing on timber mats. These foundations will be placed 2 ft below the tunnel floor under the nuclear secondary plant buildings and the conventional plant buildings. Under the reactor building this will be increased to 5 ft. Snow will be backfilled over the foundations.

The turbine-generator building, 20 ft wide, 12 ft high and 176 ft long, will be a heavily insulated prefabricated panel building and will house the secondary plant equipment, control console, shop and office equipment, decontamination facilities, and heating and ventilating equipment. A prefabricated building, 20 ft wide by 48 ft long, will be provided to enclose the condenser. The

reactor building will be a steel structure, 20 ft wide, 36 ft long, supporting the reactor and the shield tank, the spent fuel tank, and the waste retention tank. Above the reactor an insulated hoist house will provide access to the reactor equipment for maintenance and refueling. Screw jacks will be incorporated into the structure and will make it possible to level and raise the hoist house and equipment simultaneously to correct for excess or differential settlement of the foundations. A shaft to the surface through the tunnel roof over the spent fuel tank will be provided for the placing and removal of the spent fuel cask.

Heating and ventilation will be provided for the power plant building, heat being supplied by reactor steam. Cold outside air will be conveyed through the plant tunnel for the removal of heat loss from the buildings. This tunnel ventilation will be sufficient to maintain the snow temperature close to its yearly average and thereby minimize foundation settlements. A "cold well" will be provided to draw cold air from the snow during the summer should this additional cooling be required for the foundation under the reactor to remove excess heat due to conduction and gamma heating.

The stand-by diesel generator building, 16 ft wide, 12 ft high and 164 ft long, will provide space for the diesel generators and accessories, electrical switchgear, shop and office equipment.

Ventilation and exit shafts will be constructed through the tunnel roof.

Heating and ventilation will also be provided for the stand-by power plant building. Warm air from the building will be utilized for tempering combustion air to the diesel engines.

A tunnel providing space for oil storage, one one side of the main station access tunnel, will be constructed approximately 100 ft from the diesel generator plant in a direction away from the station installation. The tunnel will be 24 ft wide by 360 ft long. Fuel oil will be stored in four 55,000 gal inflatable rubber tanks. The tanks will rest on the floor of the tunnel and when filled will be 19 ft wide, 80 ft long and 6 ft high. Oil from the storage tunnel will be pumped to a day tank in the power plant building.

Fuel oil will be delivered to the site in 4,000 gal heavy duty rubber tanks mounted on a skid base.

At McMurdo Sound one 5,480 barrel steel storage tank will be constructed for bulk storage of fuel oil prior to delivery to the site.

Potable water and make-up water to the plant will be supplied from existing station facilities.

Fire protection equipment will consist of portable chemical extinguishers located in the buildings, the plant tunnels and oil storage tunnels.

B. Basis for Project Cost Estimate

1.0 Land and Land Rights

Land and property acquisition are not included in this estimate.

2.0 Structures and Improvements

2.1 General Improvements

2.1.1 Snow Tunnels

Snow excavation for the plant tunnels is based on the use of the Peter Snow Miller manufactured by Konrad Peter, Ltd., Liestal, Switzerland. The Miller is capable of cutting a trench to a depth of 24 ft below the snow's surface, the depth being determined by the limitation in ejecting the snow to the surface. Tunnels deeper than 24 ft will require excavation in stages. Snow fill deposited by the Miller sets up in a firm mass, having a density equal to the natural density of snow at a depth of 30 ft or more. This fill provides a suitable foundation material. As indicated on the drawings, the sills supporting the roof arch bear on a pad of this redeposited snow fill.

The construction of the tunnel and pit for the nuclear power plant will require approximately 18,000 cu yd of snow excavation and 6,400 cu yd of fill.

The construction of the tunnel for the stand-by diesel plant will require approximately 5,500 cu yd of snow excavation and 2,400 cu yd of fill.

The construction of the tunnel for the fuel oil storage tanks will require approximately 11,000 cu yd of snow excavation and 2,700 cu yd of fill.

That portion of the main access tunnel serving the power plant and fuel oil storage tunnels will be 250 ft long, 24 ft wide, and 24 ft deep, and will require 6,500 cu yd of excavation and 2,700 cu yd of fill.

Construction access ramps and connecting tunnel sections to and from the floor of the tunnels will require an additional 3,200 cu yd of excavation and 300 cu yd of fill.

2.1.2 Tunnel Roofs

Steel arches supported on timber sills on each side of the trench will span the tunnel and will be covered by 3 ft of snow fill. The arch will consist of double curved and corrugated zinc coated 18 gauge steel Series 3510, as manufactured by the Wonder Building Corporation of America, Chicago, Illinois. The main corrugations are 7-7/8 in. deep.

Arches over the reactor plant, turbine-generator and condenser building will span 27 ft with a rise of one-fourth the span. The top of the arch will be approximately at original snow line. This location permits a minimum clearance of 4 ft at any point between the arch and the building beneath it and places the foundation pad of the arch at 6 ft 6 in. below the original snow level. The tunnel arches over the diesel generator plant will be of similar construction and will have an over-all span of 23 ft.

Arches over the main access tunnel will span 19 ft with a rise of one-fourth the span. The top of the arch will be approximately at original snow level, placing the foundation pad of the arch at 5 ft 6 in. below the original snow level.

2.1.3 Water Supply

Power plant and domestic water requirements of approximately 100 gal per day will be supplied from existing station snow melting facilities and delivered in drums to the power plants. This water will be stored in two 250 gal storage tanks, one located in the stand-by diesel generator building and one in the turbine-generator building.

2.1.4 Sanitary Sewage Disposal

Sanitary waste will be collected in containers and disposed of by methods conforming to existing station procedure.

2.1.5 Tunnel Lighting

General tunnel lighting will be provided.

2.1.6 Fire Extinguishing Equipment

Fire extinguishing equipment for the tunnel area will consist of portable dry type chemical extinguishers.

2.2 Turbine-Generator Buildings

2.2.1 Substructure

The substructure of the buildings will consist of timber floor joists at 4 ft centers spanning 14 ft with a 3 ft cantilever on each side. A continuous timber sill will run longitudinally at 3 ft from each edge of the building. A continuous timber header will run longitudinally at each edge of the building. Solid timber blocking between floor joists will be located at the center of the building and over each longitudinal sill.

The sills will be supported by timber columns at 4 ft centers. The columns will be supported by a short transverse beam spreading the load to a continuous timber plank mat running longitudinally the length of the building.

Footings for the buildings have been sized to minimize differential settlement. Snow bearing pressures under the footings will not exceed 500 psf from both dead load and live load.

Footings will be founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor.

The building substructure will be designed to facilitate jacking and shimming to level the building in the event of differential settlement.

2.2.2 Superstructure

The superstructure is based on an Army T-5 building as developed by the Engineering Research and Development Laboratory, U. S. Army, Fort Belvoir, Virginia for Arctic use.

The turbine-generator building will be 176 ft long, 20 ft wide and 12 ft high; the condenser building will be 48 ft long by 20 ft wide. These buildings will consist of heavily insulated, prefabricated, 4 ft wide plywood panels for floor, roof and walls. The panels will have a heat transmission factor of not more than 0.10 Btu/hr/sq ft/°F. Floor panels will be designed for 100 psf. Equipment and personnel access doors will be provided at each end of the buildings.

Interior surfaces will be clad with aluminum to minimize fire hazard. Floors will be covered with a suitable abrasive and fire resistant, nonslip floor covering. Exterior surfaces will be treated with fire retardant paints at time of manufacture.

The prefabricated panels and trusses of the T-5 buildings are designed to minimize site erection labor. The buildings will be preassembled at the point of manufacture to ensure proper assembly and will be packaged for air transport. They will be erected in the completed snow tunnel with floor elevation 4 ft above the tunnel floor, allowing about 2 ft of clear space under the building. The condenser building will be separated from the turbine-generator building by 8 ft. The two will be connected by a timber platform at the floor level.

2.2.3 Heating and Ventilation

The building heating and ventilation and the tunnel cooling will be a single combined system in the turbine-generator building.

A heating and ventilating unit will draw 1,300 cfm of outside air through the tunnel, heat it, humidify it and deliver it via an air duct to the ceiling diffusers. Air will leave the building through an exhaust fan into an outside air vent stack. Approximately four air changes per hour will be provided both in the building and in the tunnel. Water will be circulated through

the heating and ventilating unit by a circulating pump as described in paragraph 9.3. Heat will be supplied to the circulating water by the space heat exchanger while the reactor is in operation, and by the diesel engine water jackets while the diesels are in operation.

2.2.4 Plumbing

A lavatory, shower and chemical type toilet will be provided.

2.2.5 Building Electrical

Facilities will consist of the building lighting, grounding and power for building services other than those provided with the package unit.

2.2.6 Painting

Interior wood surfaces (not factory treated) will be coated with a fire retardant paint. Interior carbon steel surfaces will be painted.

2.2.7 Cranes and Hoists

Heavy equipment will be lifted with a portable steel frame. A 3-ton manual hoist will be provided for the heavy lifts. A 1-ton light duty manual hoist will be provided for miscellaneous service.

2.3 Reactor Building

2.3.1 Substructure

The substructure will consist of longitudinal and transverse steel and timber beams supported by a timber mat bearing on firm snow 5 ft below the tunnel floor. After construction of the foundation, snow will be backfilled to the tunnel floor level. Foundation pressure beneath the mat due to the operating load of the reactor will be approximately 400 psf.

2.3.2 Superstructure

The superstructure will consist of field bolted steel framing. This framing will be enclosed with pre-fabricated insulated plywood panels similar to the panels used on the Army T-5 buildings. The hoist

house at the operating floor level will be 20 ft by 36 ft in plan. The lower portion containing the reactor and shield tank, the spent fuel tank and the waste retention tank will be 16 ft wide by 34 ft long.

The floor framing for the hoist house will support the reactor plant equipment. The entire upper building, including the operating floor and the reactor plant equipment can be raised or lowered by eight screw jacks built into the structure. This may be accomplished from the operating floor level and is provided to correct for excess or differential settlement of the foundations.

A monorail beam at the center of the hoist house ceiling will accommodate the 3-ton hoist used to refuel the reactor.

A 6 ft diameter shaft through the roof of the hoist house and tunnel arch will permit the removal of the 25,000 lb spent fuel cask.

2.3.3 Cooling System

A pressure blower, located in the condenser building adjacent to the reactor, will draw 3,000 cfm air at approximately -52° F from an air well. The cold well will consist of a 16 in. diameter slotted pipe extending 50 ft below the tunnel surface. This air will be pumped to a pair of buried 14 in. diameter perforated pipes at each reactor located just above the reactor footings. It will then pass through the snow covering the footings into the reactor enclosure. A 14 in. diameter perforated pipe around the periphery of the reactor enclosure overhead will collect the air in such a manner that the flow will be evenly distributed in the space between the building and the tunnel walls. A fan will exhaust this air to the atmosphere.

2.3.4 Building Electrical

Facilities will consist of the building lighting, grounding and power for building services other than those provided with the package unit.

2.4 Stand-by Diesel Generator Building

2.4.1 Substructure

The substructure of the building will consist of timber floor joists at 4 ft centers spanning 16 ft. A continuous timber sill will run at the longitudinal edges of the building. These sills will be supported by timber columns at 4 ft centers. The columns will be supported by a short transverse beam spreading the load to a continuous timber plank mat running longitudinally the length of the building.

Footings for the building have been sized to minimize differential settlement. Snow bearing pressures under the footings will not exceed 500 psf from both dead load and live load.

Footings will be founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor.

The building substructure will be designed to facilitate jacking and shimming to level the building in the event of differential settlement.

2.4.2 Superstructure

The superstructure will be an Army type T-5 building 164 ft long, 16 ft wide, and 12 ft high. Construction will be similar to that described for the turbine-generator building.

2.4.3 Heating and Ventilation

The heating and ventilation system of the stand-by plant building will work in conjunction with the turbine-generator building system as described in paragraph 2.2.3 and the diesel engine cooling system as described in paragraph 9.3.

2.4.4 Plumbing

A lavatory and a chemical type toilet will be provided.

2.4.5 Building Electrical

Facilities will consist of building lighting, grounding and power for building services other than those provided with the package unit.

2.4.6 Miscellaneous Cranes and Hoists

A 1-ton and a 3-ton manual light duty hoist will be provided.

2.4.7 Painting

Interior wood surfaces (not factory treated) will be coated with a fire retardant paint. Interior carbon steel surfaces will be painted.

3.0 Reactor Plant

3.1 Reactor

The reactor portion of the plant will include the stainless steel clad pressure vessel 52 in. ID and 18 ft high; the core structural supports and the steam drier contained in the pressure vessel; the rack-and-pinion control rod drives mounted on the top head of the pressure vessel; and the vertical sections of an 11.5 ft diameter carbon steel shield tank which will surround the pressure vessel. Also included will be a shipping container for spent fuel, a spent fuel transfer cask, lead shielding, the reactor vessel support tank (which also serves as the lower neutron shield), ducting, insulation and heaters.

The pressure vessel and head (including rod drives) will be shipped on one air transportable skid. The vertical sections of the shield tank will be packaged in four sections on a single skid. The spent fuel cask will require a shipping skid and a separate airlift. It is expected that the remainder of the equipment can be shipped as one airlift. The equipment price includes the cost of skid, assembly of equipment on the skid and export packing.

Required site work will include erection of the pressure vessel on the support tank; welding of the shield tank vertical sections and welding of this assembly to the support tank; installation of shielding, ducting, heaters and the reactor core; and control rod alignment. Interconnections are required to the purification skid, turbine-generator skid and the feed and condensate skid.

3.2 Feed and Condensate Skid

The following items are included in the feed and condensate skid:

30 cu ft stainless steel hotwell for operation at 6 in. Hg abs

10 gpm low pressure drain pump

150 gal stainless steel low pressure drain tank

Two 53 gpm condensate pumps at 122 ft TDH

Steam jet air removal equipment

1,700,000 Btu/hr shell and tube space heat exchanger

Two 192 gpm circulating pumps at 94 ft TDH (space heat system)

29,000 Btu/hr shell and tube rod drive seal water cooler

2,500 lb/hr cartridge type raw water demineralizer

5 gpm make-up water pump

25 cu ft stainless steel make-up water storage tank

598,000 Btu/hr closed feed-water heater

Two 70 gpm feed-water pumps at 1,660 ft TDH

Two 12.5 gpm lube oil cooling pumps

Stainless steel lube oil cooling system surge tank

150,000 Btu/hr shell and tube lube oil system cooler

Valves, filters, traps and strainers, pipe and insulation and local controls are also included. The skid is pre-assembled in a single air transportable shipping package at the factory. Site work includes locating the skid on the floor of the turbine building and making the required interconnections.

3.3 Waste and Spent Fuel Storage Tanks

The waste tank will be a 500 cu ft stainless steel tank located adjacent to the reactor shield tank. The waste tank will collect and store all radioactive waste from the plant and will be sized to store approximately three volumes of reactor coolant. The stainless steel spent fuel storage tank will be also located adjacent to the shield tank. Spent fuel elements and the spent fuel transfer cask can be stored in this tank.

The two tanks will be bolted together for shipment on a single air transportable shipping skid. Site work will include bolting the tanks to their supports and making interconnections to the reactor, purification skid and (for the waste tank) to the plant drains.

3.4 Purification Skid

The purification skid will include two heat exchangers, two disposable cartridge ion-exchange demineralizers, a hold-up tank, two 5 gpm purification system pumps, piping and local controls. Also located on this skid will be a tank for storage of reactor poison used for reactor shut-down.

The purification skid will be preassembled at the factory and shipped as a single air transportable package. Site work will include locating the skid on the floor of the turbine building and making the required inter-connection.

3.5 Miscellaneous Equipment

Miscellaneous reactor plant equipment which requires field assembly includes the reactor drains, decontamination equipment (solvent storage tanks, drains, basin, etc.), a 128,000 Btu/hr submerged shield water cooler, and a 130,000 Btu/hr shell and tube fuel pit vent condenser. This equipment will be shipped as a portion of an airlift of miscellaneous equipment.

3.6 Piping

The reactor plant valves, piping, fittings and insulation not installed on skids at the factory will be shipped separately and installed at the site. This piping includes the main steam line from the reactor to the turbine and the feed-water return line from the feed and condensate skid to the reactor. It is expected that one airlift will be sufficient to ship this material to the site.

4.0 Turbine-Generator Plant

4.1 Turbine-Generator Skid

The turbine-generator skid will include the turbine-generator, turbine-generator auxiliaries and local controls, and a lube oil purifier and motor controller. The marine type turbine will be designed to operate with saturated steam at 600 psia. A single extraction point at 65 psia will be provided. The generator will be 750 kva, 4-wire, 3 phase, 0.8 power factor, 60 cycle, 480 v.

The turbine-generator will be assembled on its skid before shipment to the site. Installation at the site will consist of locating the skid on the turbine-generator foundation provided in the turbine building and making interconnections to the reactor and condenser.

4.2 Condenser Skid

The installed condenser skid will consist of an air cooled condenser capable of condensing 13,000 lb/hr of steam at a pressure of 8 in. Hg abs, louvered side panels, and intake and exhaust ductwork. The equipment will be shipped as two airlifts, one for the skid mounted condenser fans and tubes and one for the louvers and ductwork. On site installation will consist of placing the skid in the separate condenser building, installation of the louvers and ductwork, and connecting the piping from the turbine and to the feed and condensate skid.

4.3 Piping

The turbine-generator plant piping will include the following systems:

- Main steam
- Turbine exhaust
- Condensate drain
- Lube oil
- Make-up water
- Service water

It is expected that this material will be shipped as a part of an airlift containing other miscellaneous equipment as described in paragraph 6.0.

4.4 Turbine-Generator Foundation

The turbine-generators will be mounted on steel skid frames at the factory. The skid will be supported by a heavy timber frame separated from the building floor framing. Braced timber columns will carry the load to a timber mat 2 ft below the tunnel floor.

After installation of the substructure, snow will be back-filled to the level of the tunnel floor. Provision will be made to facilitate jacking and shimming to correct for differential settlement.

5.0 Accessory Electrical Equipment

5.1 Electrical Skid

The electrical skid will include metal clad switchgear for 480 v service, a static exciter for the generator, voltage regulator, batteries, and controls. Also included will be the plant control console, nuclear instrumentation, radiation monitoring, indicators, recorders, alarms, controllers, test equipment and instrument wiring. The equipment will be skid mounted in the factory and the control console will be wired. Site installation will consist of locating the skid in the turbine building, making the required wiring interconnections to other skids and the reactor, and installing the reactor core instrumentation.

5.2 Main Switchgear

An additional 480 v switchgear with 25,000 amp interrupting capacity breakers will be provided for connection of the main breaker of the packaged unit to a common bus for parallel operation with the stand-by diesel engine generators. This common bus in turn will be connected through air circuit breakers to distribution feeders.

6.0 Miscellaneous Power Plant Equipment

6.1 Fire Extinguishing Equipment

Fire extinguishing equipment will consist of portable chemical extinguishers located throughout the plant.

6.2 Fire Alarm System

The fire alarm system will consist of temperature rate-of-rise detection stations appropriately located throughout the plant to actuate electrically operated alarms.

6.3 Shop Equipment

Shop equipment will include a 200 amp output d-c generator welder, a milling machine, a drill press, a bench grinder, a lathe, a machinist's bench vise and miscellaneous hand tools.

6.4 Office Furniture and Equipment

Furniture and equipment for the office will be provided.

6.5 Start-up and Emergency Heating Equipment

A package boiler capable of 3,000 lb/hr of steam at 70 psig and a diesel oil day tank will be provided for emergency heating during reactor shutdown. Start-up power will be provided by the stand-by diesel plant. The package boiler can be shipped as a portion of an airlift of miscellaneous equipment.

6.6 Laboratory Equipment

The laboratory equipment will consist of the equipment necessary for personnel monitoring, coolant sample testing, and radiation survey tests. Included will be a hand and foot counter, portable survey instruments, a water monitor, a counter-scaler, film badges and dosimeters and associated equipment. Also included will be the equipment for blood testing and urinalysis and assorted hardware and glassware. This equipment will be crated for export shipment and shipped as a portion of one of the airlifts required for miscellaneous equipment.

7.0 Transmission Plant

Cable and supports are included to the main access tunnel.

8.0 Communication System

Telephone facilities will be provided.

9.0 Stand-by Diesel Plant

9.1 Diesel Generators and Accessories

The stand-by generating system will consist of three diesel engine generating units, each rated at 250 kw, one unit serving as a stand-by. The plant will be complete with all the necessary operating auxiliaries.

The diesel engines will be heavy duty, 720 rpm, vertical, inline, single acting, two or four cycle, solid injection, completely enclosed and full pressure lubricated.

The generators will be 312 kva, 4-wire, 0.80 power factor, 3-phase, 480 v, with 125 v, d-c, V-belt connected exciter. The quality of the power will be consistent with the system requirements.

9.2 Combustion Air System

The diesel engines will draw combustion air from a common plenum. The building ventilation air will be exhausted into the plenum with outside air being drawn into the plenum only in sufficient quantity to make up the difference between the aspiration requirements and the ventilation exhaust.

9.3 Engine Cooling System

A water circulating pump, stand-by pump, suction surge tank, and an air cooled heat exchanger will be provided for cooling the diesel engines. The diesel engine cooling system will operate in conjunction with the building heating system as described in paragraph 2.2.3. The engines will be kept warm when idle by circulation of hot water from the building heating system through the engine water jackets.

9.4 Diesel Generator Foundations

The diesel generators will be mounted on steel skid by the vendor. Vibration control devices will be installed between the skid and the supporting heavy timber frame. Timber columns will carry the load to a timber mat founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor.

Provision will be made to facilitate jacking and shimming the diesel generator foundations to correct for differential settlement. The diesel generator foundations will be separated from the building floor structure.

9.5 Diesel Engine Lubrication System

Each diesel engine generating unit will have its own lube oil cooling and circulating system. The lube oil circulating pump will be engine driven. A separate lube oil transfer pump with its stand-by will transfer lube oil between the engine crankcases and a centrifuge system.

9.6 Instruments

A gaugeboard will be provided for each diesel generating unit. In addition to the unit controls, instruments will be provided for integrated plant operation of the generating units.

9.7 Plant Piping

Piping for the plant will include the following systems:

- Lube oil
- Fuel oil
- Jacket-cooling water
- Exhaust piping

9.8 Engine Starting System

Each engine will be equipped for electric starting from a battery source. The starting system will include an electric starting motor with magnetic and hand starting switches.

9.9 Auxiliaries Foundations

Auxiliaries foundations will be mounted on the building floor.

9.10 Accessory Electrical Equipment

This equipment will include one distribution panel board, 480 v, 3-phase, 60 cycle; one 125 v d-c distribution panel; and station battery and battery chargers. Controls, relaying and metering will be provided for the diesel engine generators, exciters and distribution feeders.

10.0 Fuel Oil Storage and Distribution System

10.1 Fuel Oil Storage System

The fuel oil storage system will consist of 4 static storage tanks (inflatable type) of 55,000 gal capacity each, 19 ft wide, 80 ft long and 6 ft high when full, and 22 ft wide by 83 ft long when empty. The total storage capacity of 5,240 barrels will provide 12 months-supply of fuel oil.

The storage tanks will be placed lengthwise directly on the fuel oil storage tunnel floor and to one side. The remaining space will be used by unloading and distribution piping and a service aisle.

10.2 Fuel Oil Distribution

The fuel distribution system is designed for arctic grade diesel fuel oil with a pour point of -80° F.

The fuel oil distribution system will consist of 550 lf of flexible hose pipe connected to two positive displacement pumps placed in a pit at the head of the fuel oil storage tunnel.

The pumps are controlled by and supply fuel to the day tanks located within the stand-by diesel generator building.

10.3 Fuel Oil Unloading - Pole Station

Facilities for delivery of fuel oil to the site by air from McMurdo Sound will include sled mounted 4,000 gal, extra heavy, inflatable portable tanks, 7.5 ft wide, 37 ft long and 7 ft high when full. The tanks will be unloaded at the air strip where two skid mounted gasoline engine driven fuel oil transfer pumps will pump fuel oil through 1,000 lf of 4 in. flexible hose to the plant's permanent fuel oil storage tanks.

10.4 Fuel Oil Storage - McMurdo Sound

At McMurdo Sound one 5,480 barrel steel storage tank, 70 ft in diameter and 8 ft high, will be provided to store bulk oil for transfer by tote tanks to the Pole Station.

11.0 Indirect Cost

11.1 General Field Expense

General field expense includes the cost of supervision by the Navy and by contractors' representatives, Navy service personnel, warehousing, warehouse equipment, small tools, consumable supplies, and maintenance of temporary facilities.

11.2 Export Packing and Transportation Costs

11.2.1 Export Packing

Export packing includes the cost of packing and crating sufficient for severe shipping conditions in Antarctic waters and over-the-ice transportation to NAF McMurdo. In addition packages must be finally assembled on sleds or skids for transportation by C-130-B aircraft from McMurdo to Pole Station and to facilitate unloading at Pole Station and final movement to the construction site. Packing,

crating and palletizing will preferably be done at the factory or at Davisville, Rhode Island. However, it is anticipated that some work will have to be done by Navy Construction Battalion personnel after arrival at McMurdo. The cost of export packaging of the PL-2 Nuclear Power Plant has been included in the equipment prices.

11.2.2 Ocean Freight

Ocean freight includes domestic freight forwarding charges, port handling and wharfage charges, and ocean freight from Davisville, Rhode Island to McMurdo Sound. The estimate is based on a shipping quantity of 933 short tons of cargo (Table 7), a storage factor of 1.5, and an estimated unit cost for ocean freight of \$100/mt (Appendix A).

Marine insurance is not included since shipment will be in U. S. Government owned vessels.

11.2.3 Icebreaker Cost

Icebreaker cost is based on an estimated cargo of 933 short tons, a storage factor of 1.5, and an estimated unit cost for icebreaker service of \$76/mt (Appendix B).

11.2.4 Cost of Airlift

All personnel, materials, and equipment must be flown from NAF McMurdo to Pole Station, and in addition, certain materials and equipment airlifted from New Zealand. The estimate of cost is based on a total of 71 round trip airlifts (Table 7), and an estimated unit airlift cost of \$7,570 per round trip (Appendix C). In addition, the estimate includes an allowance for the ferrying cost (Appendix C) of four cargo aircraft (Table 7) from the United States and return.

11.3 Start-up and Testing

11.3.1 Shop Testing

Shop testing includes the complete testing and operation of the assembled nuclear power plant systems and physical dimensional matching of all parts and components at the nuclear manufacturer's plant prior to shipment.

11.3.2 Field Start-up and Testing

Field start-up and testing includes all labor, materials, equipment and personnel transportation cost for the initial testing, start-up and regulating of the power plant. Acceptance tests to verify the performance of components and the completed power plant in accordance with the specifications will be performed.

11.4 Contractor's Field Overhead

This item includes an allowance of \$14,000 per man-year for Navy personnel for special clothing and transportation of men and supplies. Also included is an allowance for similar items for contractor's personnel used to supervise the installation of the nuclear power plant. Purchasing and expediting, field tests, survey, job photographs and field office supplies.

11.5 Construction Plant

It is assumed that construction personnel will make maximum use of the existing facilities at Pole Station and NAF McMurdo. However, the facilities at Pole Station will have to be augmented with additional temporary housekeeping facilities for some of the construction personnel. It is also assumed that necessary temporary construction buildings such as shops, warehouses, and field offices will be provided.

11.6 Construction Equipment

Costs are included for the Peter Snow Miller, two D-6 tractors, welding machines and miscellaneous tools and equipment required for building and equipment erection.

11.7 Camp Expenses

This includes messing and billeting of contractor's personnel, which will be furnished by the Navy at a cost of \$2.25 per day per man (Ref. 15).

11.8 Insurance, Bond, and Financing

Since all field work will be done by Navy personnel, the cost of these items is not included.

11.9 Personnel Mobilization

This includes the pay of Navy construction personnel in the U. S. while in training and in transit to and from the Pole Station.

12.0 Escalation

Escalation is based on an over-all escalation of 6% on labor, equipment and materials.

13.0 Design Engineering

Design engineering costs include the cost of over-all project planning, site layout, conceptual and detail design of the snow tunnels, buildings, diesel engine generator plant, fuel handling and storage facilities, utilities, and site-adapting the PL-2 nuclear power plant. Also included is the cost of preparing operating manuals, test procedures and maintenance manuals.

14.0 Contingency

The contingency is 20% of the cost of the plant including escalation and design engineering.

15.0 Fuel Oil in Storage

The initial complement of fuel for Pole Station is 217,000 gallons. This is sufficient fuel to operate the stand-by power plant at 200 kw and supply the stations oil fired unit heaters for a 12-month period, or to operate the stand-by power plant at 500 kw for an approximate $7\frac{1}{2}$ -month period.

It is assumed that on the average the stand-by power plant will operate at full load (500 kw) approximately 10% of the time during scheduled reactor shutdowns and refueling. On this basis the annual fuel consumption of the diesel generators is estimated to be 34,000 gallons. The difference between the total quantity of fuel oil in storage (217,000 gal) and the anticipated average annual consumption of 34,000 gal represents an emergency reserve supply of fuel, which will always remain in storage at the station. Accordingly, purchase cost for 183,000 gal of fuel oil, shipping cost to McMurdo, and handling and airlift cost to the Pole Station are included in the estimate.

C. Estimate of Project Cost

SUMMARY

500 KW NUCLEAR POWER PLANT

<u>Description</u>	<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
1.0 Land and Land Rights	\$ - -	\$ - -	\$ - -
2.0 Structures and Improvements	136,000	321,000	457,000
3.0 Reactor Plant	45,000	1,086,000	1,131,000
4.0 Turbine-Generator Plant	19,000	283,000	302,000
5.0 Accessory Electrical Equipment	15,000	266,000	281,000
6.0 Miscellaneous Power Plant Equipment	11,000	50,000	61,000
7.0 Transmission Plant	2,000	5,000	7,000
8.0 Communication System	3,000	3,000	6,000
9.0 Stand-by Diesel Plant	33,000	197,000	230,000
10.0 Fuel Oil Storage and Distribution	24,000	76,000	100,000
Total Direct Construction Cost	\$ 288,000	\$2,287,000	\$2,575,000
11.0 Indirect Cost	160,000	2,223,000	2,383,000
Total Construction Cost	\$ 448,000	\$4,510,000	\$4,958,000
12.0 Escalation			302,000
Total Including Escalation			\$5,260,000
13.0 Design Engineering			400,000
Total Excluding Contingency			\$5,660,000
14.0 Contingency			1,140,000
Total Including Contingency			\$6,800,000
15.0 Fuel Oil in Storage			600,000
Total Project Cost			\$7,400,000

ESTIMATE OF CONSTRUCTION COST

500 KW NUCLEAR POWER PLANT

<u>Description</u>	<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
1.0 <u>Land and Land Rights</u>	—	—	—
2.0 <u>Structures and Improvements</u>			
.1 General Improvements			
.1.1 Snow Tunnels	\$ 7,000	\$ -	\$ 7,000
.1.2 Tunnel Roofs	11,000	50,000	61,000
.1.3 Water Supply	1,000	2,000	3,000
.1.4 Sanitary Sewage Disposal	1,000	2,000	3,000
.1.5 Tunnel Lighting	4,000	10,000	14,000
.1.6 Fire Extinguishing Equipment	1,000	2,000	3,000
Sub-Total	\$ 25,000	\$ 66,000	\$ 91,000
.2 Turbine-Generator Building			
.2.1 Substructure	\$ 9,000	\$ 5,000	\$ 14,000
.2.2 Superstructure	28,000	90,000	118,000
.2.3 Heating and Ventilation	4,000	11,000	15,000
.2.4 Plumbing	2,000	4,000	6,000
.2.5 Building Electrical	6,000	8,000	14,000
.2.6 Painting	1,000	3,000	4,000
.2.7 Cranes and Hoists	1,000	1,000	2,000
Sub-Total	\$ 51,000	\$ 122,000	\$ 173,000
.3 Reactor Building			
.3.1 Substructure	\$ 7,000	\$ 13,000	\$ 20,000
.3.2 Superstructure	12,000	38,000	50,000
.3.3 Cooling System	2,000	5,000	7,000
.3.4 Building Electrical	2,000	2,000	4,000
Sub-Total	\$ 23,000	\$ 58,000	\$ 81,000
.4 Stand-by Diesel Generator Building			
.4.1 Substructure	\$ 10,000	\$ 5,000	\$ 15,000
.4.2 Superstructure	17,000	55,000	72,000
.4.3 Heating and Ventilation	2,000	4,000	6,000
.4.4 Plumbing	2,000	3,000	5,000
.4.5 Building Electrical	4,000	5,000	9,000
.4.6 Miscellaneous Cranes and Hoists	1,000	1,000	2,000
.4.7 Painting	1,000	2,000	3,000
Sub-Total	\$ 37,000	\$ 75,000	\$ 112,000
Total Structures and Improvements	\$ 136,000	\$ 321,000	\$ 457,000

ESTIMATE OF CONSTRUCTION COST

500 KW NUCLEAR POWER PLANT
(Cont'd)

	<u>Description</u>	<u>Labor</u>	<u>Permanent Material and Equipment</u>	<u>Total</u>
3.0	<u>Reactor Plant</u>			
.1	Reactor	\$ 15,000	\$ 611,000	\$ 626,000
.2	Feed and Condensate Skid	4,000	228,000	232,000
.3	Waste and Spent Fuel Storage Tanks	10,000	31,000	41,000
.4	Purification Skid	3,000	46,000	49,000
.5	Miscellaneous Equipment	9,000	42,000	51,000
.6	Piping	4,000	128,000	132,000
	Total Reactor Plant	\$ 45,000	\$1,086,000	\$1,131,000
4.0	<u>Turbine-Generator Plant</u>			
.1	Turbine-Generator Skid	\$ 8,000	\$ 183,000	\$ 191,000
.2	Condenser Skid	5,000	58,000	63,000
.3	Piping	3,000	40,000	43,000
.4	Turbine-Generator Foundation	3,000	2,000	5,000
	Total Turbine-Generator Plant	\$ 19,000	\$ 283,000	\$ 302,000
5.0	<u>Accessory Electrical Equipment</u>			
.1	Electrical Skid	\$ 11,000	\$ 239,000	\$ 250,000
.2	Main Switchgear	4,000	27,000	31,000
	Total Accessory Electrical Equipment	\$ 15,000	\$ 266,000	\$ 281,000
6.0	<u>Miscellaneous Power Plant Equipment</u>			
.1	Fire Extinguishing Equipment	\$ 2,000	\$ 5,000	\$ 7,000
.2	Fire Alarm System	2,000	5,000	7,000
.3	Shop Equipment	1,000	10,000	11,000
.4	Office Furniture and Equipment	-	5,000	5,000
.5	Start-up and Emergency Heating Equipment	4,000	9,000	13,000
.6	Laboratory Equipment	2,000	16,000	18,000
	Total Miscellaneous Power Plant Equipment	\$ 11,000	\$ 50,000	\$ 61,000
7.0	<u>Transmission Plant</u>	\$ 2,000	\$ 5,000	\$ 7,000
8.0	<u>Communication System</u>	\$ 3,000	\$ 3,000	\$ 6,000

ESTIMATE OF CONSTRUCTION COST

500 KW NUCLEAR POWER PLANT

(Cont'd)

<u>Description</u>		<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
9.0	<u>Stand-by Diesel Plant</u>			
.1	Diesel Generators and Accessories	\$ 13,000	\$ 135,000	\$ 148,000
.2	Combustion Air System	1,000	3,000	4,000
.3	Engine Cooling System	1,000	2,000	3,000
.4	Diesel Generator Foundations	1,000	1,000	2,000
.5	Diesel Engine Lubrication System	2,000	6,000	8,000
.6	Instruments	1,000	3,000	4,000
.7	Plant Piping	4,000	5,000	9,000
.8	Engine Starting System	1,000	1,000	2,000
.9	Auxiliaries Foundations	1,000	1,000	2,000
.10	Accessory Electrical Equipment	8,000	40,000	48,000
	Total Stand-by Diesel Plant	\$ 33,000	\$ 197,000	\$ 230,000
10.0	<u>Fuel Storage and Distribution System</u>			
.1	Fuel Oil Storage System	\$ 2,000	\$ 31,000	\$ 33,000
.2	Fuel Oil Distribution	3,000	9,000	12,000
.3	Fuel Oil Unloading - Pole Station	3,000	23,000	26,000
.4	Fuel Oil Storage - McMurdo Sound	16,000	13,000	29,000
	Total Fuel Storage and Distribution System	\$ 24,000	\$ 76,000	\$ 100,000
	Total Direct Construction Cost	\$ 288,000	\$2,287,000	\$2,575,000
11.0	<u>Indirect Cost</u>			
.1	General Field Expense	\$ 72,000	\$ 64,000	\$ 136,000
.2	Export Packing and Transportation Costs			
.2.1	Export Packing	\$ -	\$ 30,000	\$ 30,000
.2.2	Ocean Freight	-	125,000	125,000
.2.3	Icebreaker Cost	-	95,000	95,000
.2.4	Cost of Airlift	-	772,000	772,000
	Sub-Total	\$ -	\$1,022,000	\$1,022,000
.3	Start-up and Testing			
.3.1	Shop Testing	\$ -	\$ 120,000	\$ 120,000
.3.2	Field Start-up and Testing	24,000	6,000	30,000
	Sub-Total	\$ 24,000	\$ 126,000	\$ 150,000

ESTIMATE OF CONSTRUCTION COST

500 KW NUCLEAR POWER PLANT
(Cont'd)

<u>Description</u>		<u>Labor</u>	Permanent Materials and <u>Equipment</u>	<u>Total</u>
.4	Contractor's Field Overhead	\$ 40,000	\$ 620,000	\$ 660,000
.5	Construction Plant	16,000	50,000	66,000
.6	Construction Equipment	8,000	175,000	183,000
.7	Camp Expenses	-	6,000	6,000
.8	Insurance, Bond, and Financing	-	-	-
.9	Personnel Mobilization	-	160,000	160,000
	Total Indirect Cost	\$ 160,000	\$2,223,000	\$2,383,000
	TOTAL CONSTRUCTION COST	\$ 448,000	\$4,510,000	\$4,958,000

D. Project Schedule

The project schedule on page 53 for the 500 kw nuclear power plant has been prepared to serve as a basis for the estimate of cost. The schedule indicates that design and construction activities span a period of 26 months. Starting of engineering by January 1962, will permit completion and operation of the nuclear power plant by February 1964.

Based on the ability of aircraft to fly between NAF McMurdo and Pole Station, the maximum construction season is approximately 90 days. For periods up to one month after the start of the summer season it is not possible to get a vessel into McMurdo Sound due to ice conditions. A construction schedule based on bringing materials, equipment and personnel in by vessel would be limited to a maximum of two months of construction time.

It is assumed that existing facilities at the Pole Station would be enlarged to accommodate the construction crew, and at a later date the operating personnel, prior to the start of construction in 1962-1963 (Ref. 14). The schedule is based on such an expansion of facilities.

The schedules and cost estimates are based on the shipment of all materials from Davisville, Rhode Island, which is the CONUS marshalling point.

The estimated weights of the equipment and material required for construction of the plant are shown on Table 7 in Section III-D for estimated costs and the schedule presented herein.

In addition, the following factors were considered in preparing the schedule and form a further basis for it:

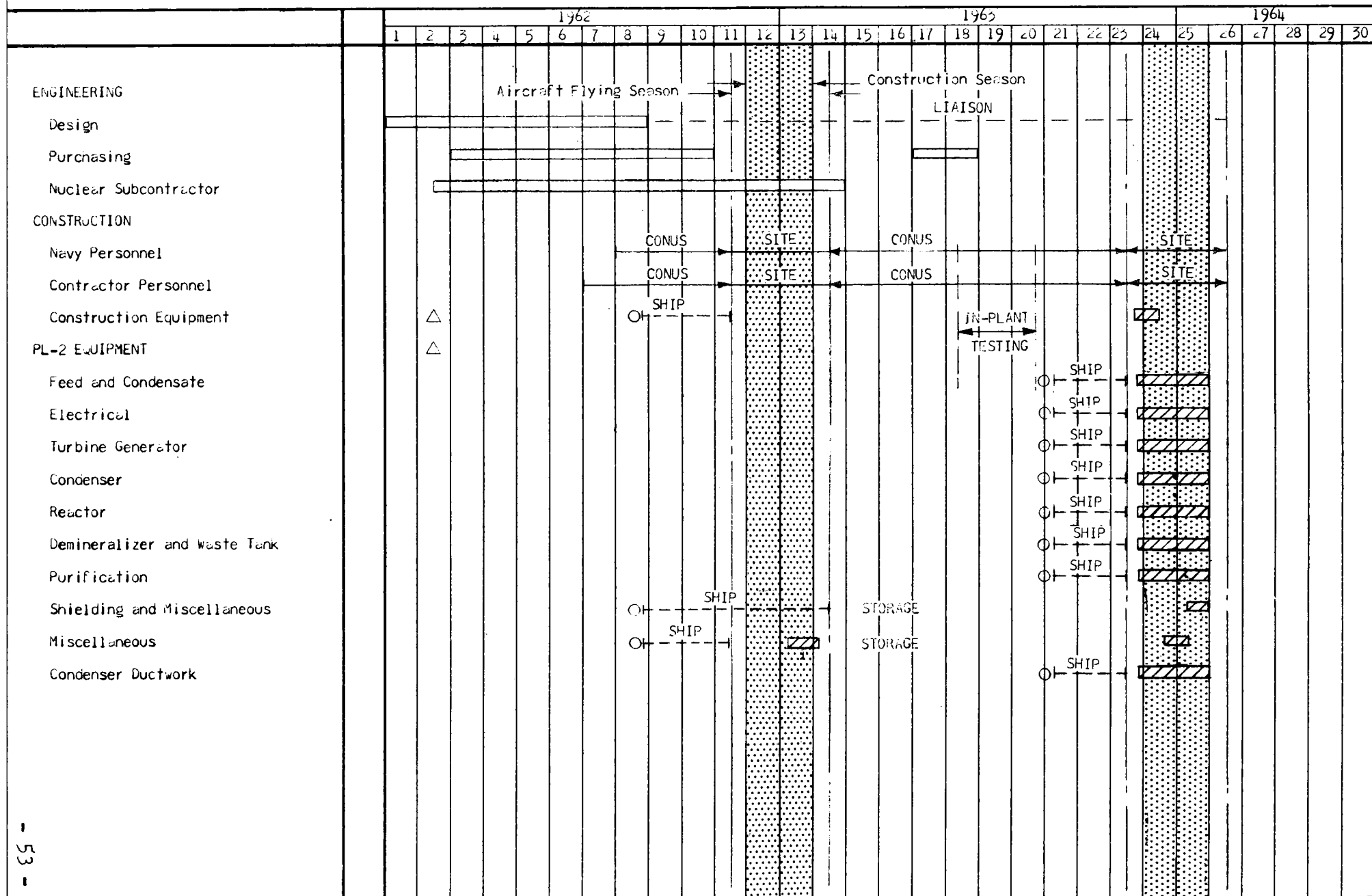
1. Performance of construction work by U. S. Navy Construction Battalion personnel under the direction of a contractor selected to be responsible for performance of the plant. Billeting and messing facilities will be furnished by the Navy.
2. A period of three months has been allowed for the mobilization and briefing of construction personnel. In addition, supervisory and key construction personnel should spend approximately one month in the nuclear subcontractor's plant during the period when the nuclear plant packages are being assembled and tested prior to shipment, to familiarize them with the equipment and techniques and problems in assembly.
3. The construction schedule is based on a six-day work week with 10-hour shifts per day.

4. It has been assumed that construction materials required the first season will be ordered far enough in advance to reach McMurdo Sound by ship not later than December 15, 1962. Shipment of the reactor packages the following year will be such as to assure arrival at Pole Station not later than December 15, 1963. The reactor equipment will be shipped by sea to New Zealand for transshipment by air to McMurdo and then to the Pole Station.
5. The schedule is based on maximum utilization of prefabricated and preassembled units, including mechanical, nuclear and electrical equipment and piping.
6. The engineering phase of the project includes adapting the available design of the PL-2 packaged nuclear power plant to the Pole Station site.
7. The schedule is based on a single contractor assuming responsibility for the design and performance of the nuclear power plant.

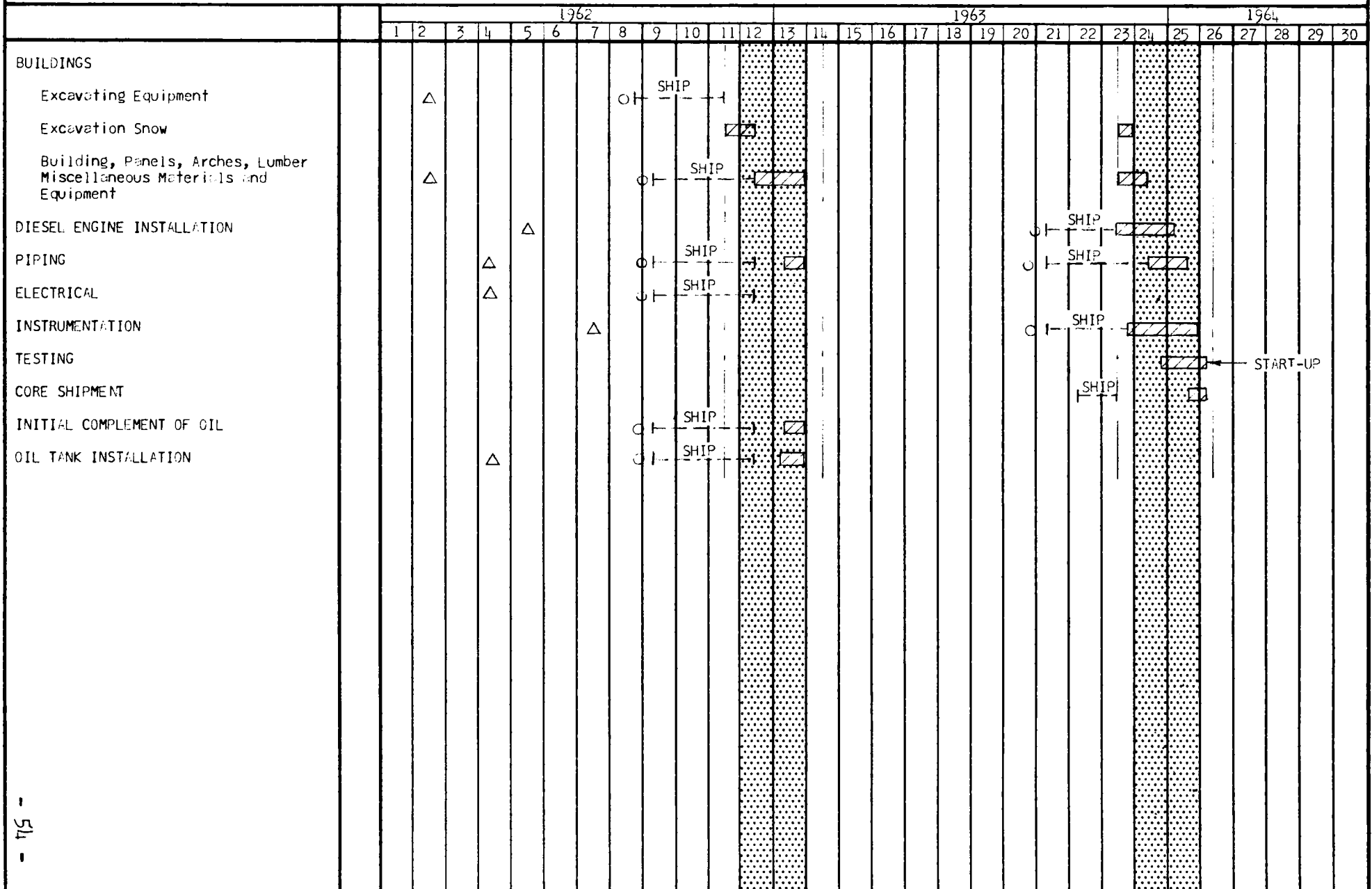
LEGEND

○ FOB Factory
 Installation
 Δ Purchase

PROJECT SCHEDULE
 500 KW NUCLEAR POWER PLANT
 POLE STATION



PROJECT SCHEDULE
500 KW NUCLEAR POWER PLANT
POLE STATION



E. Estimate of Unit Power Cost

Unit power costs have been based on a plant operating factor equivalent to 100% of the firm power requirement of 500 kw. The nuclear plant will generate 90% of the annual power and the stand-by diesel plant will generate 10%.

Annual Fixed Charges

Annual fixed charges are based on a 20-year plant life equivalent to the total project cost. No interest on the investment has been included (Ref. 16).

$$0.05 \times \$7,400,000 = \$370,000$$

Operating and Maintenance Costs

Operating and maintenance labor cost based on an estimated complement of seven military personnel is shown on Table 9, page 56. Labor costs are based on an average annual rate for overseas military personnel of \$20,350, including base pay, transportation of supplies, messing and special clothing (Ref. 10). Labor escalation of 2% per year has been included in the estimate for a 20-year period beginning in 1964. The average annual cost of maintenance materials and operating supplies for the reactor plant has been estimated as being 1% of the U. S. purchase cost. Tunnel and building maintenance costs have been added to this cost. The estimate includes allowances for export packing, shipping cost and prorated icebreaker cost, and in addition a 20% allowance for average escalation of materials and supplies over a 20-year period.

The computation and allocation of icebreaker costs and shipping costs is in accordance with methods indicated in Section IV-B, indirect costs.

TABLE 9
AVERAGE OPERATING AND MAINTENANCE COSTS

<u>Labor</u>	<u>No. of Personnel</u>	<u>Rate</u>	<u>Annual Cost</u>
<u>Supervision</u>			
Plant Superintendent	1		
<u>Operation</u>			
Reactor Operator	3		
Turbine and Auxiliary Operator	1		
<u>Maintenance</u>			
Master Mechanic	1		
Instrument Technician	<u>1</u>		
Sub-Total	7	\$20,350	\$142,000
Escalation			<u>42,000</u>
Total Operating and Maintenance Labor			\$184,000
<u>Maintenance Materials and Operating Supplies</u>			\$ 26,000
Escalation			<u>5,000</u>
Total Maintenance Materials and Operating Supplies			<u>\$ 31,000</u>
TOTAL AVERAGE ANNUAL OPERATING AND MAINTENANCE COST			\$215,000

Note: The nuclear power plant operators will be used to operate the stand-by diesel plant.

Nuclear Fuel Costs

Table 10, page 58, summarizes the fuel costs for the modified PL-2 proposed for the Pole Station. Total annual power generated is based on 100% of the 500 kw firm power requirement, 90% from the nuclear power plant and 10% from the stand-by diesel plant. Included in the annual fuel cost is the fuel requirement for heating the power plant buildings. The estimated fuel cost includes the costs of fuel preparation and fabrication, fuel burnup and spent fuel processing, and is based upon information derived from the reactor designer, Combustion Engineering, Inc. and U. S. Atomic Energy Commission published cost data. Interest on fabrication cost and fuel use charges (except during the fabrication period) are not included (Ref. 16). The nuclear fuel costs have not been escalated since it is anticipated that improvements in technology will more than offset increases in raw material or labor costs.

The core approximates a right circular cylinder of 35.6 in. equivalent diameter with a 38 in. active height. There are 24 fuel assemblies, 5.5 in. by 5.5 in. by 50 in., each containing 60 fuel tubes and 4 burnable poison (boron) tubes. The fuel tubes, on a 0.716 in. square pitch, consist of 0.48 in. diameter partially enriched UO_2 pellets clad in stainless steel. There are 9 cruciform control elements consisting of silver-indium-cadmium control material clad with stainless steel.

The fuel cycle costs calculated below are based upon a single region core with no fuel rearrangement. The entire core of 24 fuel assemblies and 9 control elements will be discharged to the spent fuel storage tank and replaced with new elements at the end of the useful core lifetime. Based on a 90% plant operating factor for the reactor and the design burnup of 25.5 mwt-yrs per core, the reactor will be shut down for refueling approximately once every 7 to 8 years.

TABLE 10
SUMMARY OF NUCLEAR FUEL COSTS

General Data

Number of reactors	1
Gross capability, kwe	675
Net capability, kwe	500
Power plant heating, kwt	400
Reactor plant operating factor	90%
Reactor thermal power, mwt (including plant heating)	3.6
Core loading, kg U	1,480
Core lifetime, mwt-yr	25.5
Core lifetime, yrs	7.9
Initial enrichment, % U-235	4.5
Depleted enrichment, % U-235	3.7
Pu concentration, g Pu/kg U	3.04
Cost of fabrication of first core (1) (includes control elements)	\$330,000

Cost Analysis

<u>Description</u>	<u>Cost Per kg U</u>	<u>Cost Per Year</u>
<u>Fuel Preparation and Fabrication (1)</u>		
UF ₆ to UO ₂ conversion and scrap recovery (1)	\$ 20.70	\$ 3,900
Fabrication and assembly (1) (including control elements)	169.30	31,700
Losses (1)	13.90	2,600
Use charge during fabrication (1)	<u>19.90</u>	<u>3,700</u>
Sub-Total	\$223.80	\$ 41,900
<u>Fuel Burnup</u>		
Value of fuel charged (2)	\$615.00	\$114,500
Value of fuel discharged (2)	<u>-487.00</u>	<u>-91,100</u>
Gross burnup	\$128.00	\$ 23,400
Pu credit (3)	<u>-31.90</u>	<u>-6,000</u>
Net burnup	\$ 96.10	\$ 17,400
<u>New and Spent Fuel Transportation</u>		
Continental U. S. (4)	\$ 15.00	\$ 2,800
Davisville, R. I., to McMurdo Sound (5)	3.80	700
McMurdo Sound to South Pole (6)	<u>17.50</u>	<u>3,300</u>
Sub-Total	\$ 36.30	\$ 6,800

TABLE 10 (Cont'd)

<u>Description</u>	<u>Cost Per kg U</u>	<u>Cost Per Year</u>
<u>Fuel Reprocessing</u>		
Processing to UNH (7)	\$ 46.60	\$ 8,700
UNH to UF ₆ conversion (8)	5.60	1,000
Material losses (9)	<u>6.60</u>	<u>1,200</u>
Sub-Total	\$ 58.80	\$ 10,900
TOTAL FUEL COST	\$415.00	\$ 77,000

-
- (1) Based on Ref. 12. Costs due to losses and use charge modified to allow for higher enrichment.
- (2) Based on U. S. AEC enriched UF₆ cost schedule (Ref. 17).
- (3) Based on \$12/g Pu as metal and \$1.50/g Pu for processing plutonium nitrate to metal.
- (4) Assumes shipment by commercial carrier, including insurance for new fuel from Windsor, Connecticut to Davisville, Rhode Island and for spent fuel cask round trip from Davisville, Rhode Island to Richland, Washington.
- (5) Based on a 15-ton load for 1/3 core; \$126/ton round trip.
- (6) Based on a 15-ton load for 1/3 core; \$583/ton round trip.
- (7) Based on Ref. 18. Batch size is full core loading.
- (8) Based on U. S. AEC charge of \$5.60 per kg U as per AEC press release dated March 12, 1958.
- (9) Assumes 1% and 0.3% losses of uranium in processing to nitrate and conversion to UF₆, respectively. Also assumes a total of 1% losses of Pu in processing to nitrate and then to metal.

Stand-by Diesel Generator Plant Cost

Annual fuel consumption for the stand-by plant is based on the assumption that the stand-by plant operates 10% of the time at full load.

Cost per gallon arctic grade fuel delivered to Pole Station (w/escalation)	\$3.87
Diesel Generator fuel rate	.55 lb/kwhr
Annual power production	438,000 kwhr
Annual fuel consumption	34,000 gallons
$34,000 \times \$3.87 = \$132,000$	

Average Unit Power Cost

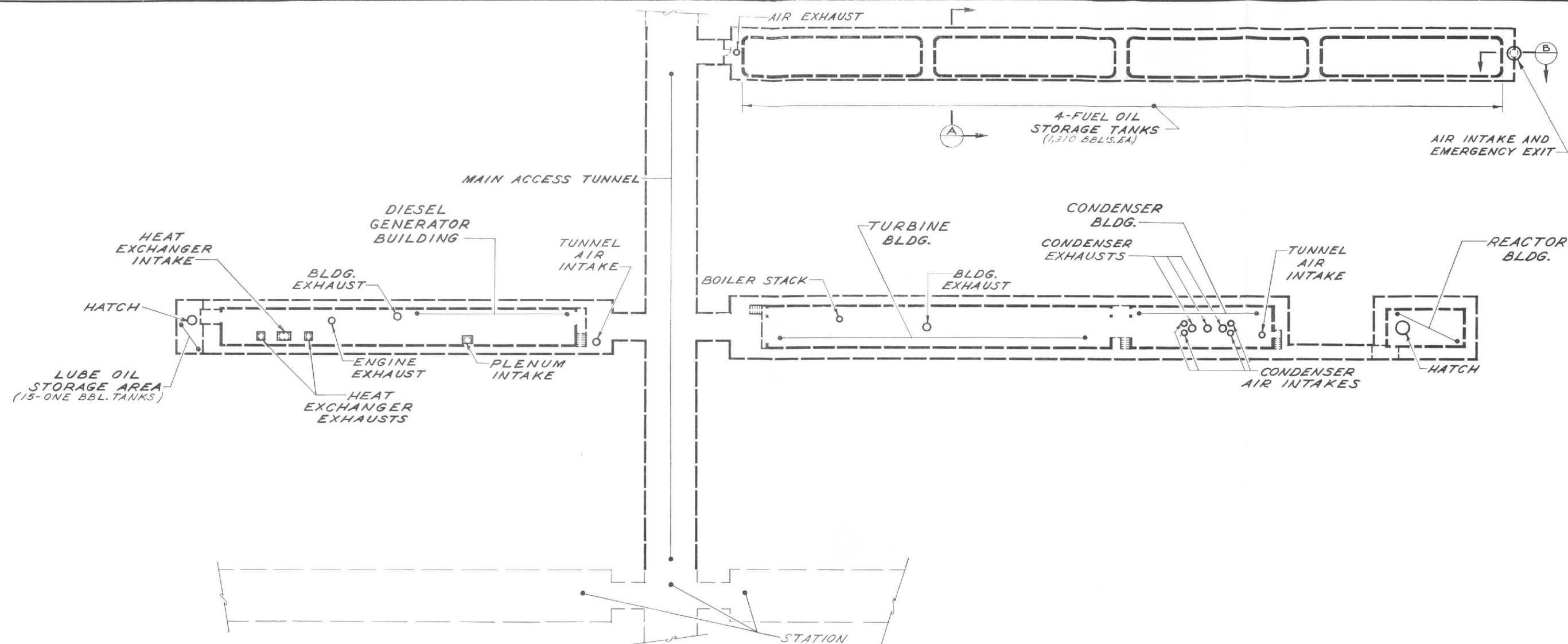
The unit power cost is based on the production of 4,380,000 kwhr per year.

	<u>Average Annual Cost</u>	<u>Mills Per Kwhr</u>
Fixed Charges	\$370,000	84.5
Operating and Maintenance	215,000	49.1
Nuclear Fuel	77,000	17.6
Stand-by Fuel Costs	<u>132,000</u>	<u>30.1</u>
TOTAL	\$794,000	181.3

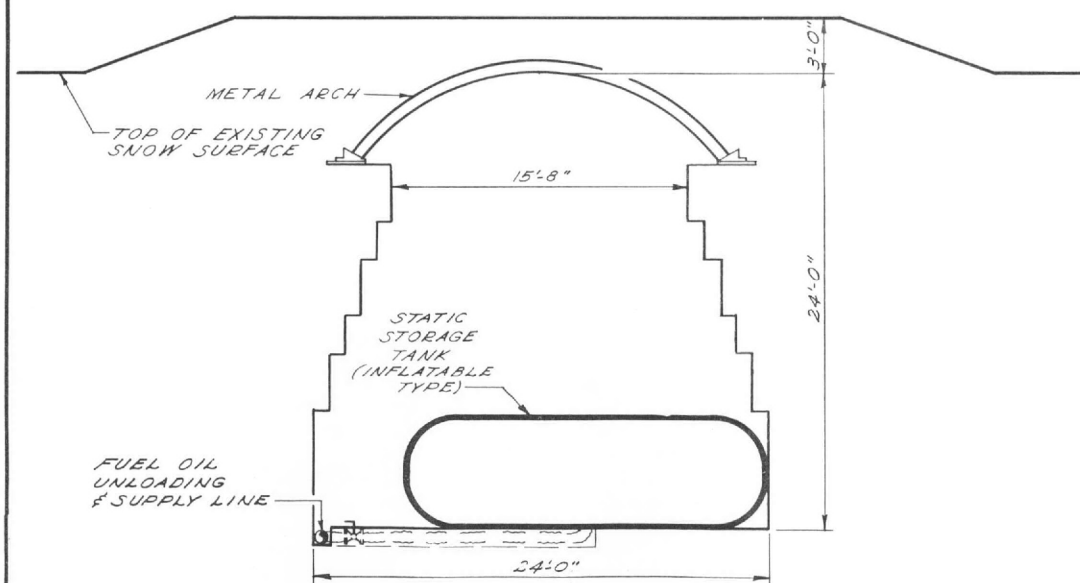
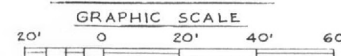
F. Concept Drawings

The following drawings present the conceptual design of the proposed 500 kw nuclear power plant.

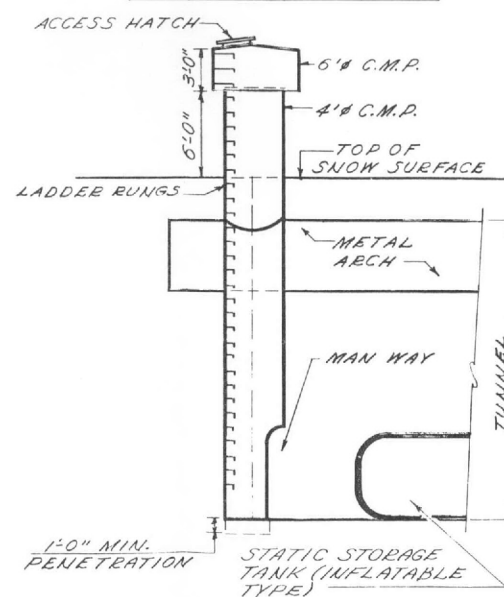
<u>Drawing No.</u>	<u>Title</u>
1503-C	Plot Plan
1502-G	General Arrangement - Plans
1503-G	General Arrangement - Elevations
1501-M	PL-2 Core Cross Section and Fuel Assembly
1502-M	PL-2 Reactor Pressure Vessel and Core
1501-P	Heat Balance
1502-P	Piping Diagram
1502-E	One Line Diagram



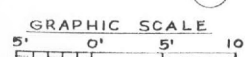
STATION
PLOT PLAN



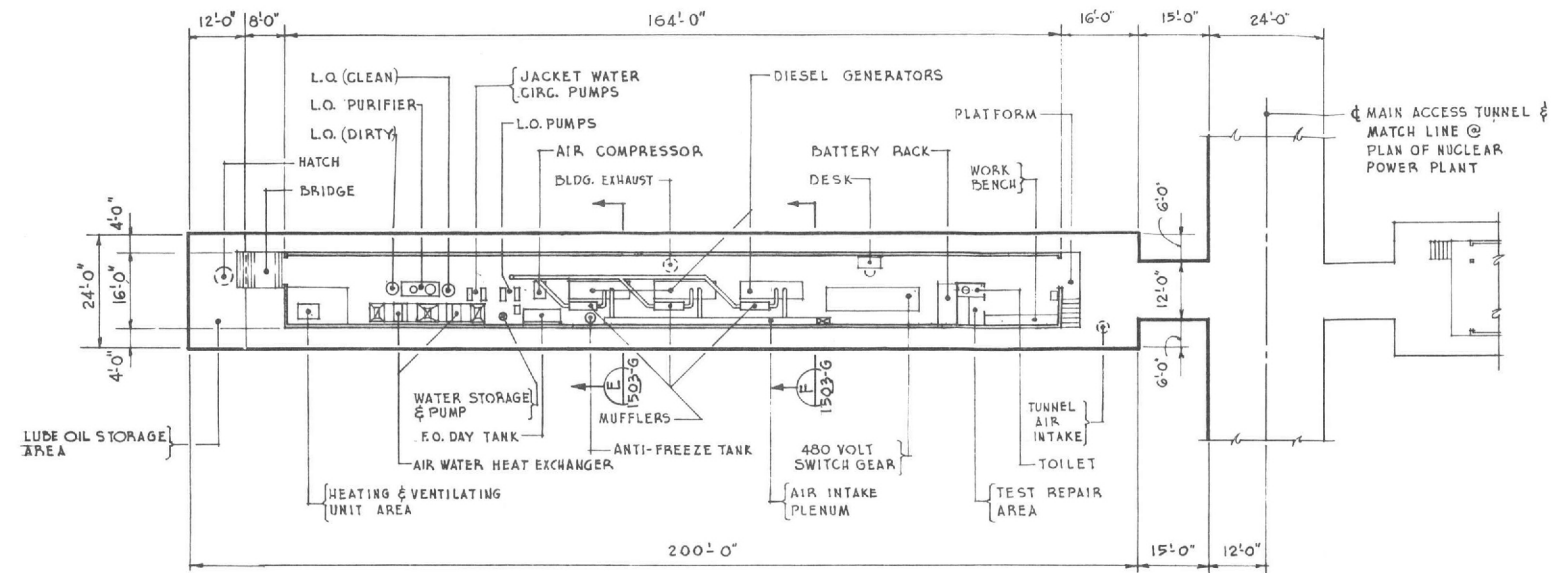
SECTION A



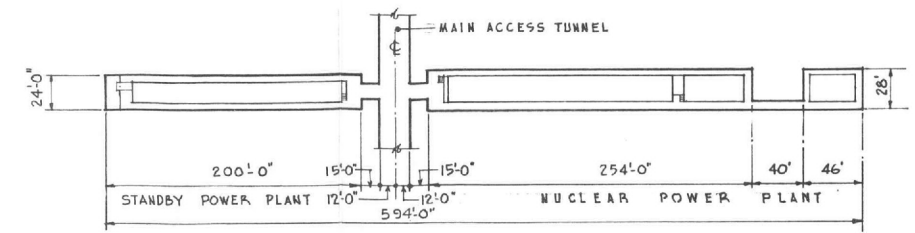
SECTION B



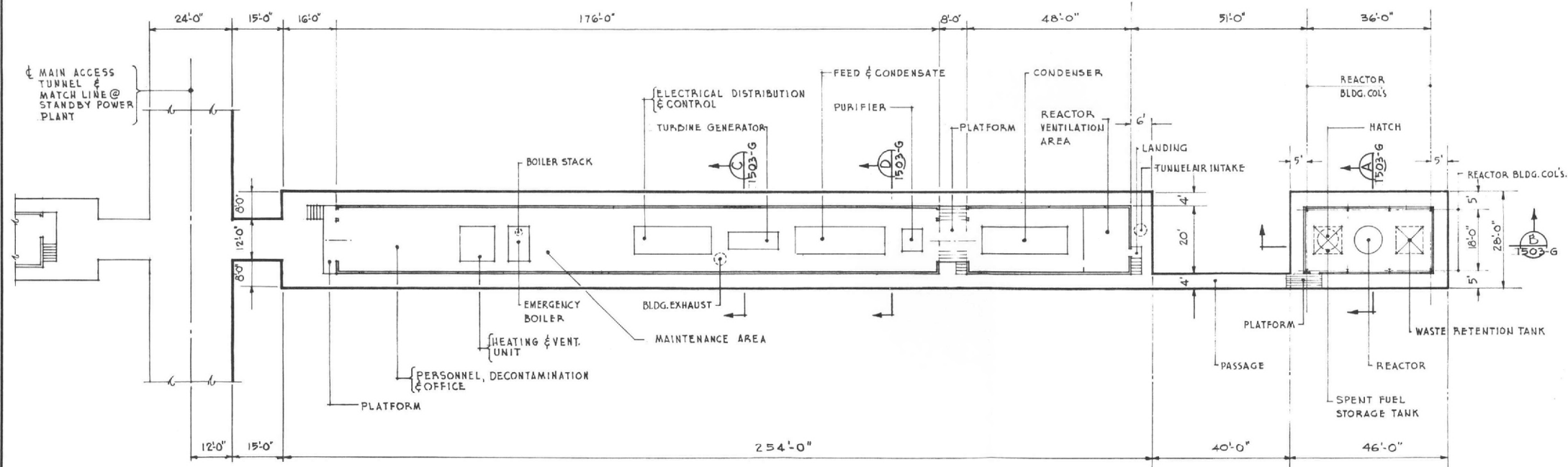
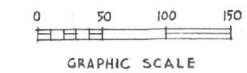
STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION						
APPROVAL		DATE	DIVISION OF HENRY J. KAISER COMPANY	K A I S E R E N G I N E E R S		OAKLAND CALIFORNIA
			SCALE	DATE	POLE STATION, ANTARCTICA	
			DRAWN BY J. MICHAEL	5-5-60	500 KW NUCLEAR POWER PLANT PLOT PLAN	
			CHECKED BY A. J. BECKWITH	5-5-60		
PROJECT ENGINEER		5/5/60	APPROVED BY	5-5-60		
CHIEF ENGINEER			CHIEF DESIGN ENGINEER	5-5-60	JOB No. 5929 DWG. No. 1503-C	



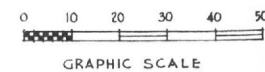
PLAN OF STANDBY POWER PLANT



KEY PLAN



PLAN OF NUCLEAR POWER PLANT



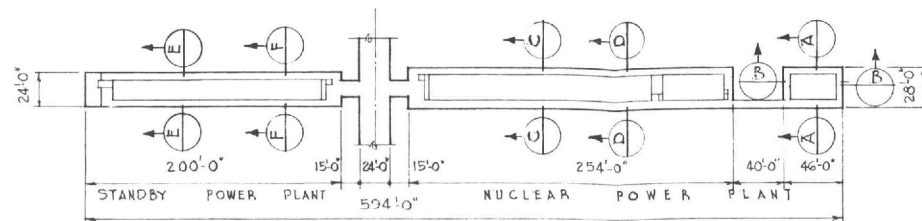
STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

KAISER ENGINEERS

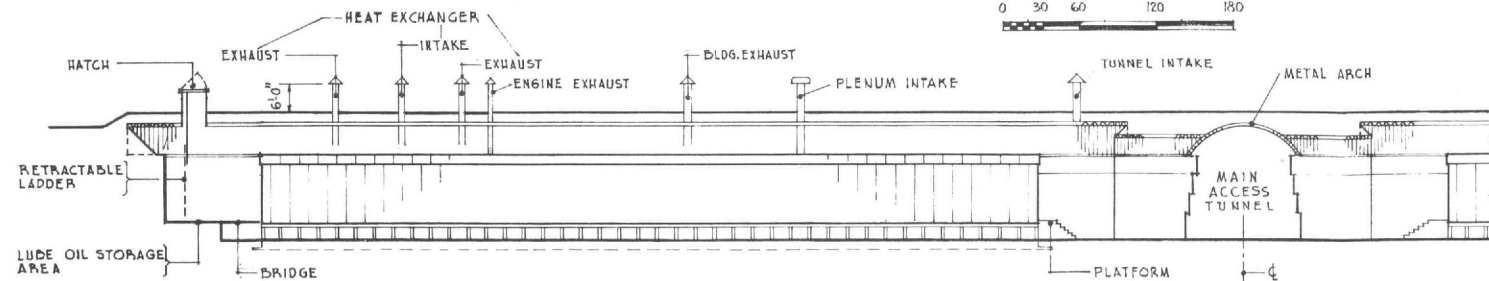
OAKLAND
CALIFORNIA

APPROVAL	DATE	SCALE	DATE	POLE STATION, ANTARCTICA
		DRAWN BY C. ROYLANCE	3/24/60	
		CHECKED BY R. A. WILSON	5/4/60	
PROJECT ENGINEER <i>D. A. Wilson</i>	5/4/60	APPROVED BY <i>R. A. Wilson</i>	5-4-60	500 KW NUCLEAR POWER PLANT GENERAL ARRANGEMENT-PLANS
CHIEF DESIGN ENGINEER		CHIEF DESIGN ENGINEER <i>R. A. Wilson</i>	5-5-60	JOB No. 5929 DWG. No. 1502-G

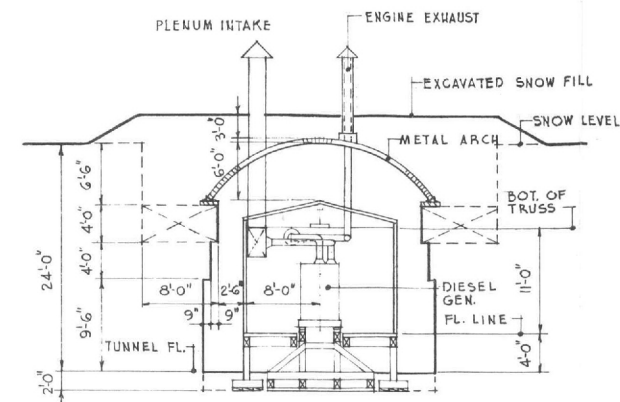
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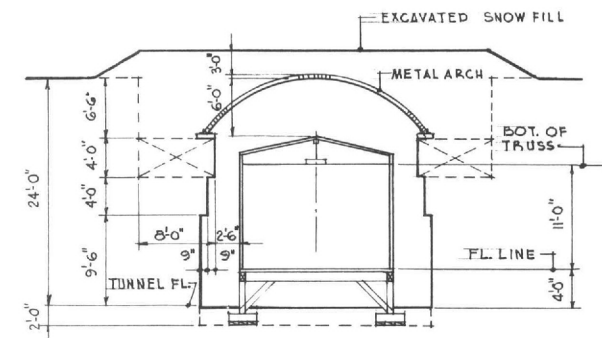
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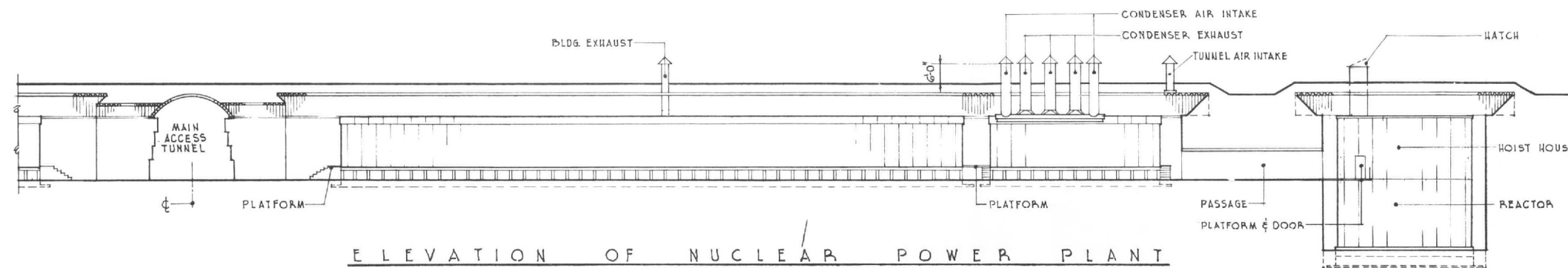
ELEVATION OF STANDBY POWER PLANT



SECTION E

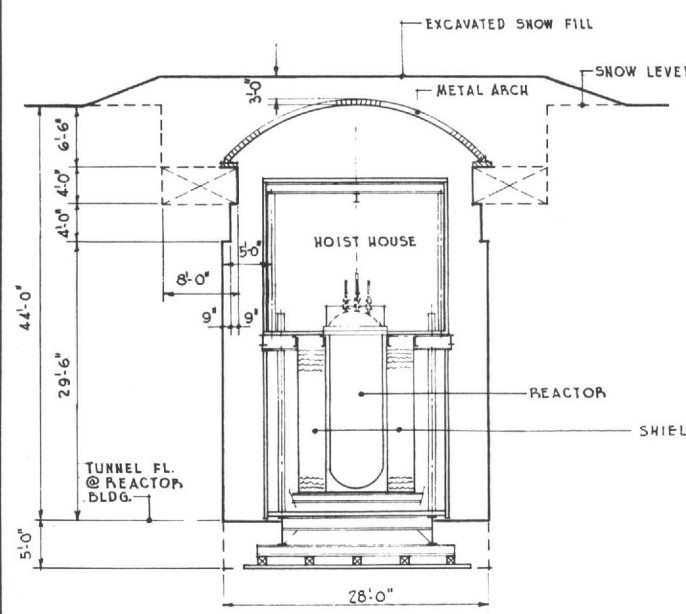


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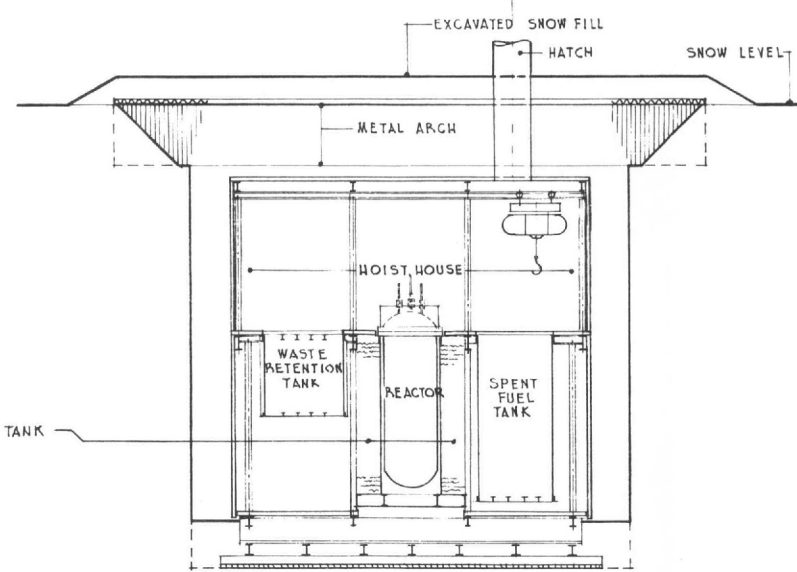


ELEVATION OF NUCLEAR POWER PLANT

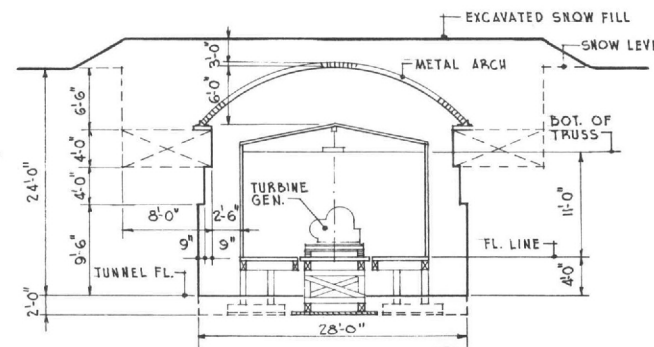
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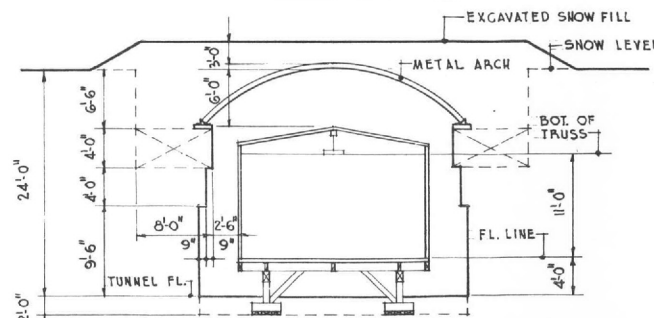
SECTION A



SECTION B



SECTION C



SECTION D

0 5 10 20 30

STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

KAISER ENGINEERS

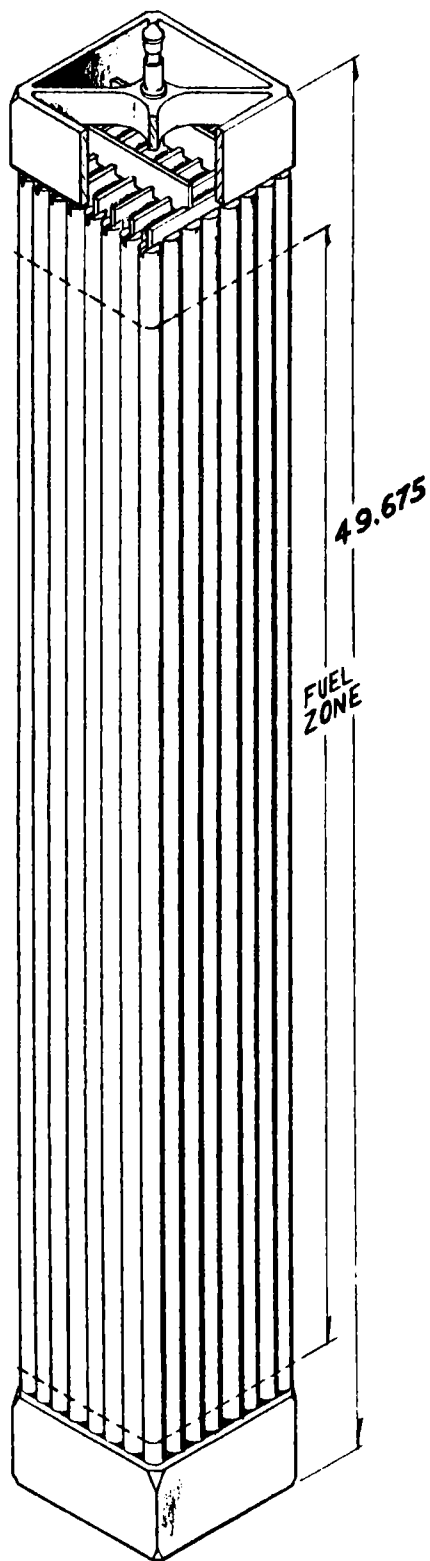
POLE STATION, ANTARCTICA

500 KW NUCLEAR POWER PLANT
GENERAL ARRANGEMENT-ELEVATIONS

JOB No. 5929 DWG. No. 1503-G

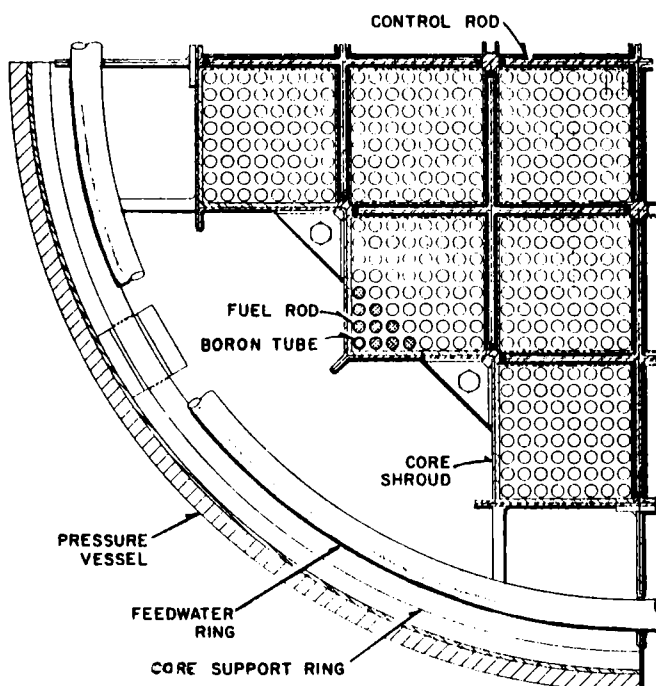
APPROVAL	DATE
PROJECT ENGINEER	5/5/60
CHIEF ENGINEER	5/5/60

SCALE	DATE
DRAWN BY C. ROYLANCE	4/12/60
CHECKED BY R.A. WILSON	5/4/60
APPROVED BY R.W. SIMPSON	5-4-60
CHIEF DESIGN ENGINEER	5-5-60



FUEL ASSEMBLY

CORE CROSS SECTION

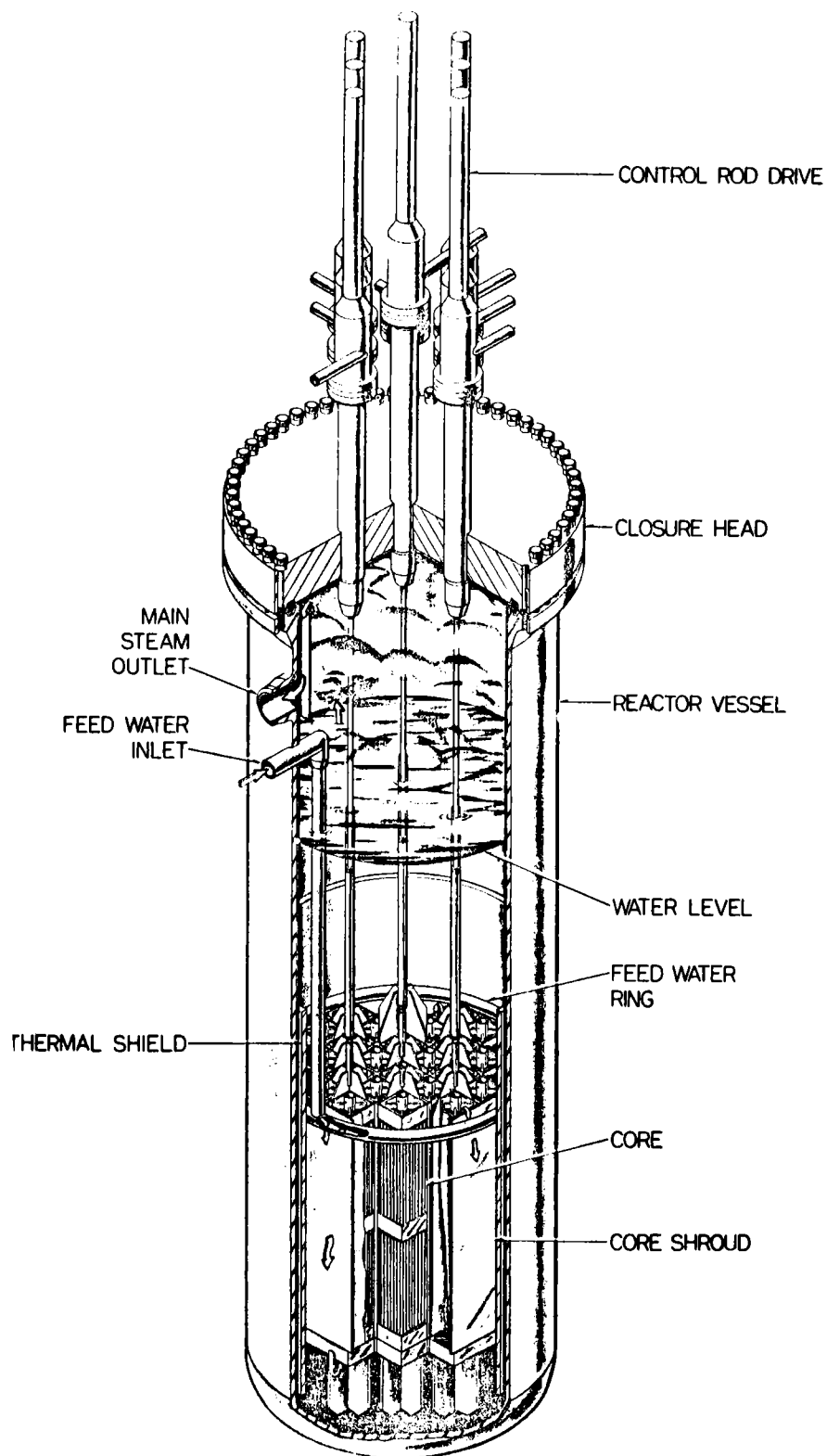


500 KW NUCLEAR POWER PLANT

PL-2 CORE CROSS SECTION
AND FUEL ASSEMBLY

COURTESY OF
COMBUSTION ENGINEERING, INC.

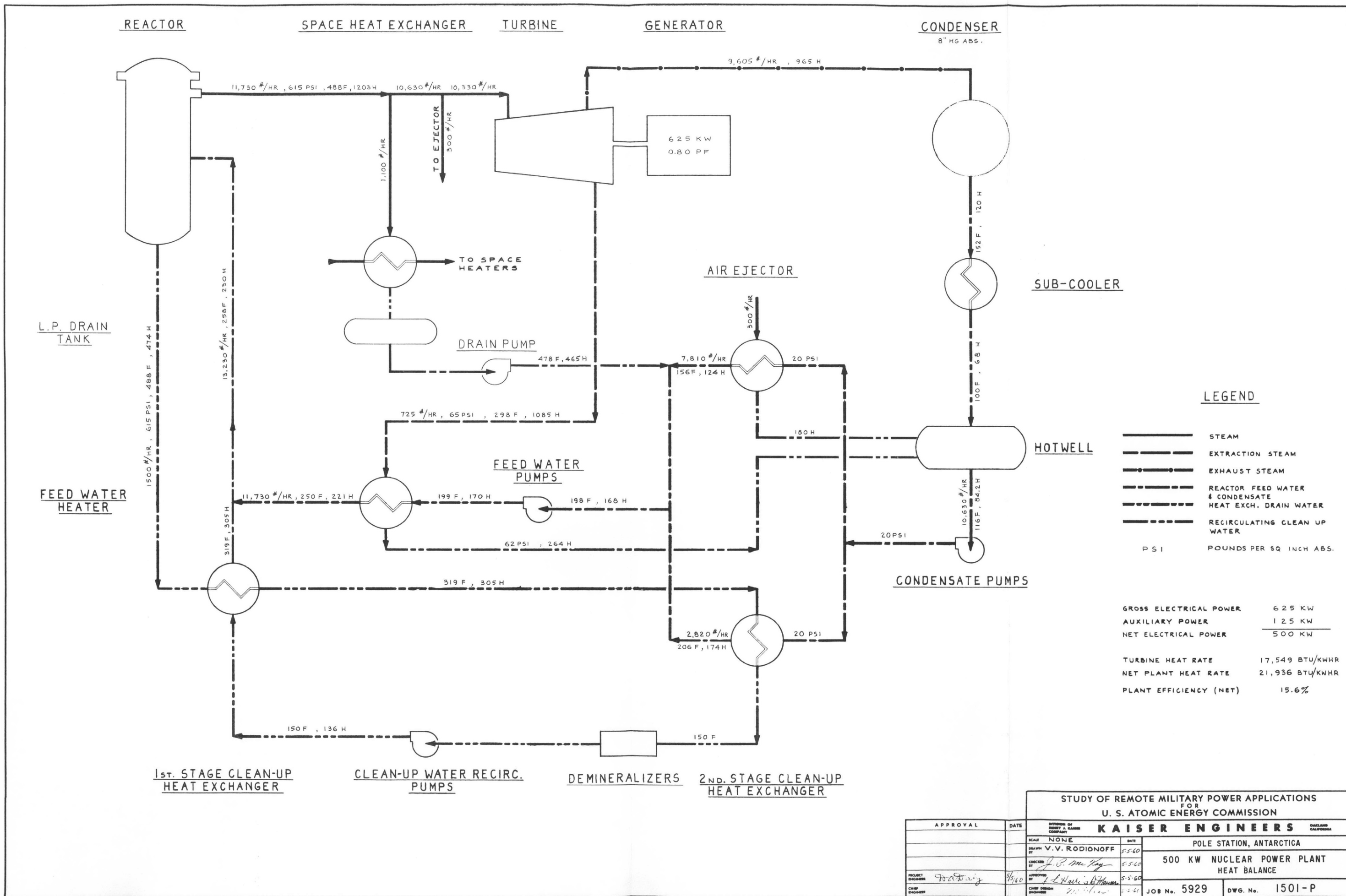
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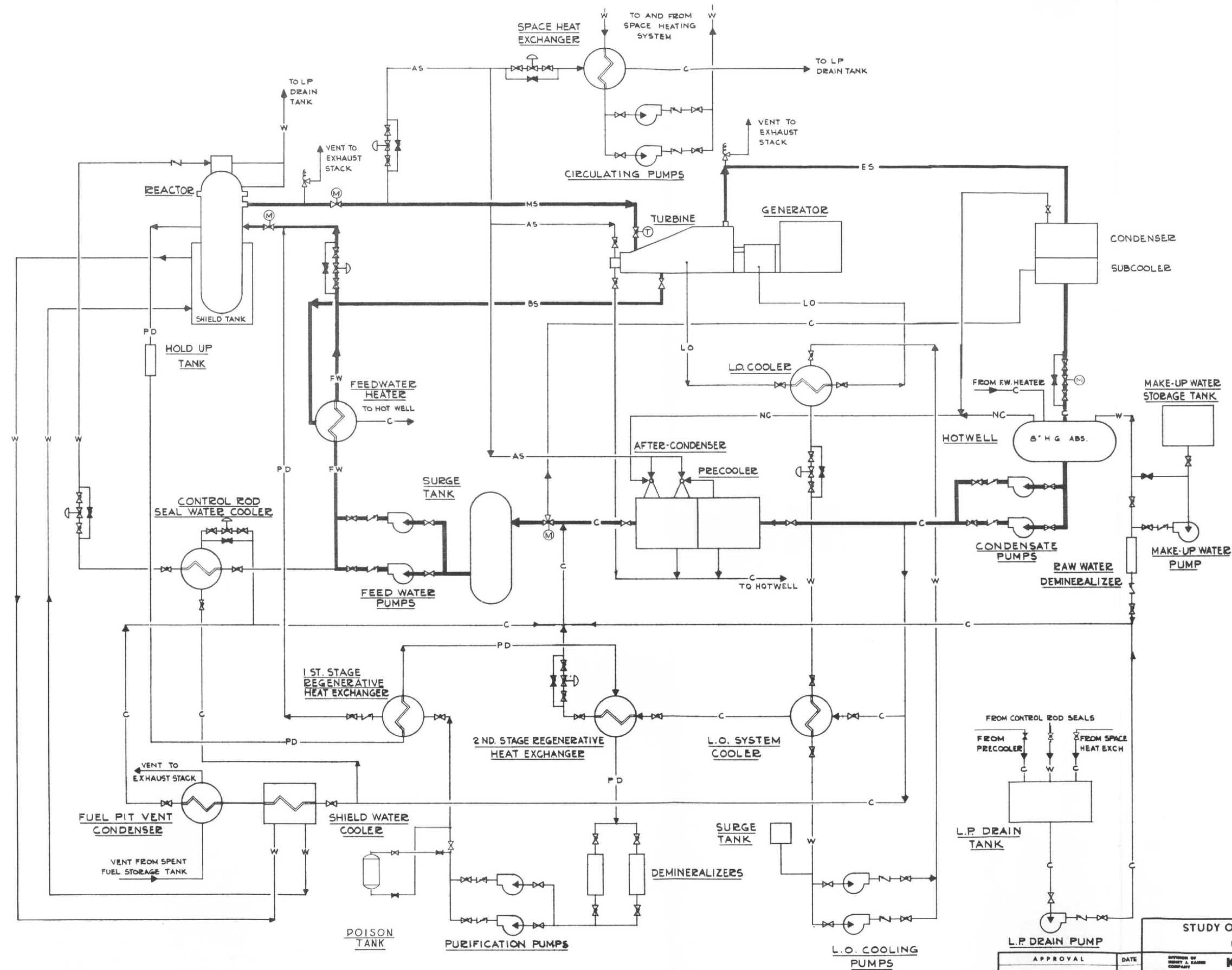
500 KW NUCLEAR POWER PLANT
PL-2 REACTOR PRESSURE VESSEL
AND CORE

COURTESY OF
COMBUSTION ENGINEERING, INC.

DWG. NO. 1502-M



STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION			
KAISER ENGINEERS			
DAELAND CALIFORNIA			
APPROVAL		DATE	SCALE
NONE		5-5-60	DATE
DRAWN BY V.V. RODIONOFF		5-5-60	DATE
CHECKED BY J.P. Mc Kay		5-5-60	DATE
PROJECT ENGINEER		5-5-60	DATE
CHIEF DESIGN ENGINEER		5-5-60	DATE
CHIEF ENGINEER		5-5-60	DATE
500 KW NUCLEAR POWER PLANT HEAT BALANCE		JOB No. 5929 DWG. No. 1501-P	



LEGEND

- MAIN PRIMARY PIPING
- MAIN SECONDARY PIPING
- MS — MAIN STEAM
- AS — AUXILIARY STEAM
- BS — BLEED STEAM
- ES — EXHAUST STEAM
- C — CONDENSATE
- W — WATER
- FW — FEEDWATER
- PD — PURIFICATION DRAIN
- NC — NON-CONDENSIBLES
- LO — LUBE OIL
- GATE VALVE
- NORMALLY CLOSED
- GLOBE VALVE
- CHECK VALVE
- CONTROL VALVE
- GLOBE VALVE, MOTOR OPERATED
- THROTTLE VALVE

NOTES

MAIN PRIMARY AND SECONDARY PIPING ONLY ARE SHOWN ON THIS DIAGRAM.

STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION

KAISER ENGINEERS

OAKLAND, CALIFORNIA

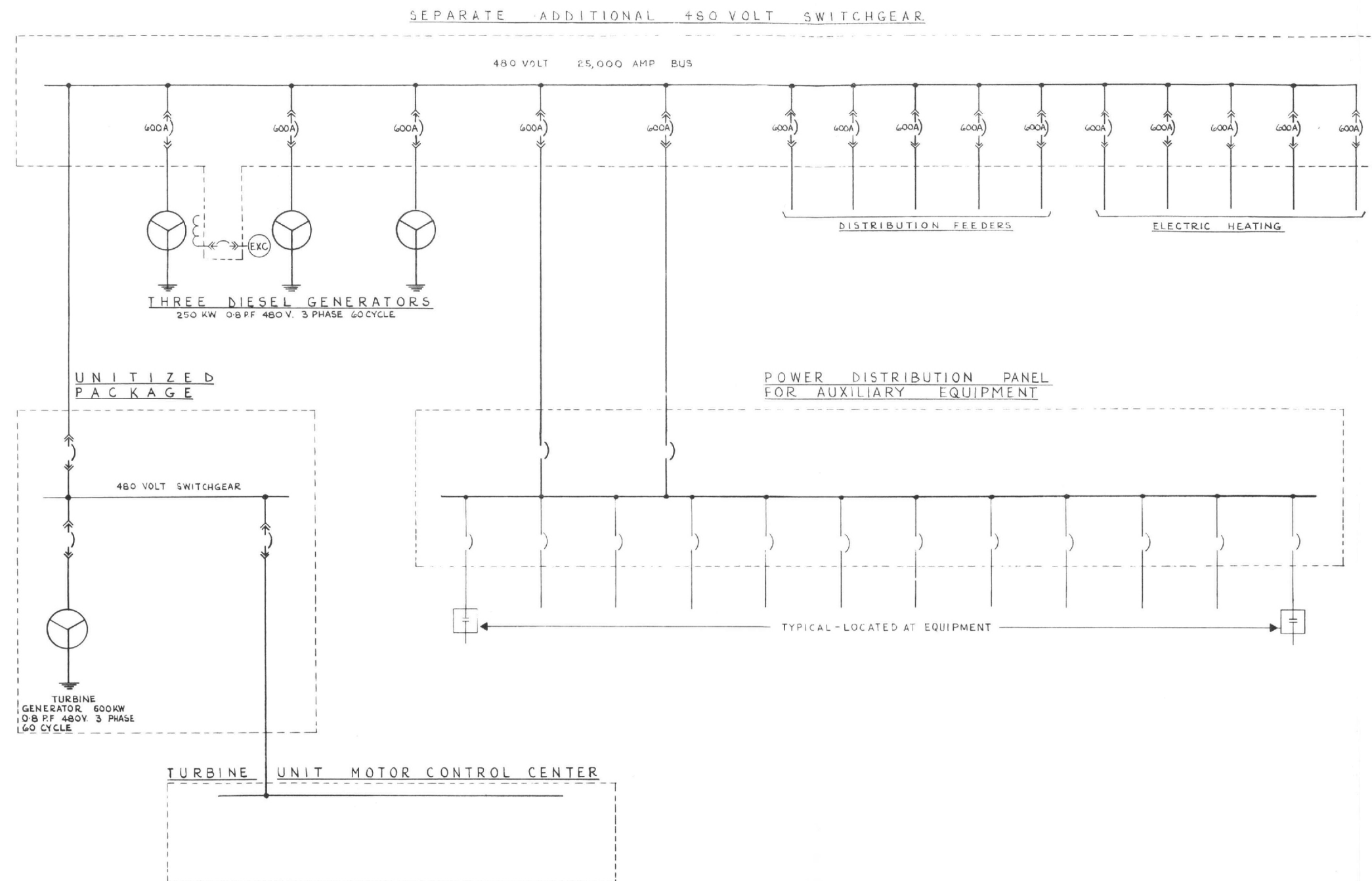
POLE STATION, ANTARCTICA

500 KW NUCLEAR POWER PLANT
PIPING DIAGRAM

JOB No. 5929

DWG. No. 1502-P

APPROVAL	DATE
SCALE NONE	DATE 5/4/60
DRAWN BY J. Sarty.	5-5-60
CHECKED BY M. J. Sarty	5-5-60
PROJECT ENGINEER D. J. Sarty	5-5-60
CHIEF DESIGN ENGINEER J. L. Harris	5-5-60



LEGEND

DRAWOUT AIR CIRCUIT-BREAKER
 AIR CIRCUIT BREAKER
 MOTOR STARTER

NOTE

GROUNDING INDICATED ON THIS DWG WILL BE PATTERNED AFTER A METHOD OF GROUNDING MATS OR GRIDS AS DESCRIBED BY E.T.B. GROSS IN A.I.E.E. TRANSACTION PAPERS ISSUED IN AUG. 1953, OCT. 1955 AND OCT 1956. THIS METHOD IS APPLIED WHERE OTHER GROUNDING SCHEMES ARE UNWORKABLE DUE TO THE HIGH RESISTIVITY OF THE GROUNDING MEDIUM.

STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION			
APPROVAL		DATE	DIVISION OF HENRY J. KAISER COMPANY KAISER ENGINEERS OAKLAND CALIFORNIA
SCALE NONE DRAWN BY G. H. HUGHES CHECKED BY O. NIEPONICE APPROVED BY <i>[Signature]</i> PROJECT ENGINEER <i>[Signature]</i> CHIEF ENGINEER		DATE 4-29-60 4-29-60 4-29-60 5-5-60	
POLE STATION, ANTARCTICA 500 KW NUCLEAR POWER PLANT ONE LINE DIAGRAM			JOB No. 5929 DWG. No. 1502-E

SECTION V

PROPOSED CONVENTIONAL POWER PLANT

A. General Description

The conventional power plant will consist of four diesel electric generators each rated at 250 kw. Fuel will be arctic grade diesel oil having a minimum pour point of -80° F. Electrical power for base heating and power will be supplied at 480 volts.

All plant facilities will be placed within snow tunnels excavated to a depth of 24 ft below the surface. A Peter Snow Miller will be used to excavate a trench to the required size and to prepare a level bench for supporting the roof arches spanning the tunnel. After erecting the steel arches, the Miller will be used to place about 3 ft of snow fill over the tunnel. Clearance between the buildings and the tunnel walls will be provided to allow for reduction in the tunnel cross section due to plastic flow and consolidation of the snow over the life of the plant.

The power plant will be housed in a heavily insulated prefabricated building designed for erection under arctic conditions with a minimum of time. Buildings and equipment will be supported by timber posts and cribbing bearing on timber mats. The mats or foundations will bear on dense snow at a depth of 2 ft below the tunnel floor. Snow will be backfilled over the foundations.

The diesel generator building, 16 ft wide, 12 ft high, and 176 ft long, will provide space for the diesel generators and accessories, electrical switchgear, shop and office equipment, and heating and ventilating equipment. The plant tunnel will be 24 ft wide by 212 ft long, and will have a 12 ft wide connecting passageway to the main station access tunnel. Ventilation and exit shafts will be constructed through the tunnel roof.

Space for oil storage will be provided in two tunnels, one on each side of the main base access tunnel, constructed approximately 100 ft from the diesel generator plant in a direction away from the base installation. Each tunnel will be 24 ft wide by 325 ft long. A total storage capacity of 9,520 barrels will provide 14 months' supply of fuel oil. Fuel oil will be stored in 8 - 50,000 gallon inflatable rubber tanks, four located in each tunnel. The tanks will rest on the floor of the tunnel and when filled will be 19 ft wide, 72 ft long, and 6 ft high. Oil from the storage tunnel will be pumped to a day tank in the power plant building.

Fuel oil will be delivered to the site by air in 4,000 gal heavy duty skid mounted rubber tanks.

At McMurdo Sound two 5,480 barrel steel storage tanks will be constructed for the bulk storage of fuel oil for delivery to the Pole.

Heating and ventilation will be provided for the power plant building. Warm air from the building will be utilized for tempering combustion air to the diesel engines. Cold outside air will be conveyed through the plant tunnel for the removal of heat loss from the building. This tunnel ventilation will be sufficient to maintain the snow temperature close to its yearly average and thereby minimize foundation settlements.

Potable water and make-up water to the plant will be supplied from existing station facilities.

Fire protection equipment will consist of portable chemical extinguishers located throughout the plant.

B. Basis for Project Cost Estimate

1.0 Land and Land Rights

Land and property acquisition are not included in this estimate.

2.0 Structures and Improvements

2.1 General Improvements

2.1.1 Snow Tunnels

Snow excavation for the plant tunnels and the oil storage area is based on the use of the Peter Snow Miller as manufactured by Konrad Peter, Ltd., Liestal, Switzerland. The Miller is capable of cutting a trench to a depth of at least 24 feet below the snow's surface, the depth being determined by the limitation in ejecting the snow to the surface. Snow fill deposited by the Miller sets up in a firm mass, having a density equal to the density of snow at a depth of 30 feet or more. This fill provides a suitable foundation material. As indicated on the drawings, the sills supporting the roof arch bear on a pad of this redeposited snow fill.

The tunnel for the diesel generator building will require 5,650 cu yd of excavation and 2,500 cu yd of fill, and will be approximately 200 ft long by 24 ft deep by 24 ft wide at the bottom. A portion of the main access tunnel, 250 ft long by 24 ft wide at the bottom by 24 ft deep, will provide access from the Station to the power plant and fuel oil storage tunnels and will require 6,500 cu yd of excavation and 2,700 cu yd of fill.

Each of two fuel storage tunnels will require an excavation 325 ft long by 24 ft wide by 24 ft deep. This will result in a total of 20,100 cu yd of excavation and 4,850 cu yd of snow backfill to cover over the storage tanks and the storage area access tunnel.

Access ramps and connecting tunnel sections to and from the floor of the tunnels will require an additional 2,500 cu yd of snow excavation.

2.1.2 Tunnel Roofs

Tunnel roofs will be of steel arch construction covered with 3 ft of snow at the arch centerline.

The arch will consist of double curved and corrugated zinc coated 18 gauge steel, Series 3510, as manufactured by the Wonder Building Corporation of America, Chicago, Illinois. The main corrugations are 7-7/8 in. deep.

Arches over the diesel generator building will span 23 ft with a rise of one-fourth the span. The top of the arch will be approximately at the original snow level. This location permits a minimum clearance of 4 ft at any point between the arch and the building beneath it, and places the foundation pad of the arch at 6 ft 6 in. below the original snow level.

Arches over the oil storage tanks will span 19 ft with a rise of one-fourth the span. The top of the arch will be approximately 3 ft below original snow level. This location places the foundation pad of the arch at 7 ft 9 in. below the original snow level.

2.1.3 Water Supply

Power plant and domestic water requirements of approximately 45 gallons per day will be supplied from existing station snow melting facilities and delivered in drums to the power plant where it will be stored in a 250 gal storage tank.

2.1.4 Sanitary Sewage Disposal

Sanitary waste will be collected in containers and disposed of by methods conforming to existing station procedures.

2.1.5 Tunnel Lighting

General tunnel lighting will be provided.

2.1.6 Fire Extinguishing Equipment

Exterior fire extinguishing equipment for the tunnel system and oil storage area will consist of portable chemical extinguishers.

2.2 Diesel Generator Building

2.2.1 Substructure

The substructure of the building will consist of timber floor joists at 4 ft centers spanning 16 ft.

A continuous timber sill will run at the longitudinal edges of the building. These sills will be supported by timber columns at 4 ft centers. The columns will be supported by a short transverse beam spreading the load to a continuous timber plank mat running longitudinally the length of the building.

Footing areas for the building will be designed to minimize differential settlement. Snow bearing pressures under the footings will not exceed 500 psf from both dead load and live load.

Footings will be founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor.

The substructure will be designed to facilitate jacking and shimming for leveling the building in the event of unequal settlement.

2.2.2 Superstructure

The superstructure is based on an Army T-5 building as developed by the Engineering Research and Development Laboratory, U. S. Army, Fort Belvoir, Virginia for Arctic use.

The building will measure 16 ft by 176 ft by 12 ft high and will consist of heavily insulated, prefabricated, 4 ft wide plywood panels for floor, roof and walls. The panels will have a heat transmission factor of not more than 0.10 Btu/hr/sq ft/°F. Floor panels will be designed for 100 psf. A pair of doors will be provided at each end of the building for equipment and personnel.

Interior surfaces will be clad with aluminum to minimize fire hazard. Floors will be covered with a suitable abrasive and fire resistant, nonslip floor covering. Exterior surfaces will be treated with a fire retardant paint at the manufacturer's plant.

The prefabricated panels and trusses of T-5 buildings are designed to minimize site erection time. The building will be preassembled at the plant to ensure proper fit-up and packaged for air transport. It will be erected in the completed snow tunnel with the finish floor 4 ft above the tunnel floor.

2.2.3 Heating and Ventilation

The building heating and ventilation and the tunnel cooling will be a single combined system.

A heating and ventilating unit in the building will draw 3,700 cfm of outside air through the tunnel, heat it, humidify it, and deliver it via an air duct to the ceiling diffusers.

Air will leave the building either through an exhaust fan or relief dampers into the diesel engine combustion air intake plenums. Approximately four air changes an hour will be provided in both the building and in the tunnel.

2.2.4 Plumbing

A chemical toilet and lavatory will be provided.

2.2.5 Building Electrical

Facilities will consist of building lighting, grounding, power for building services, and structures supporting the cable trays and electrical equipment associated with the generator's main circuits.

2.2.6 Miscellaneous Cranes and Hoists

Heavy equipment will be lifted from a portable steel tripod. A 3-ton manual hoist will be provided for the heavy lifts. A 1-ton light duty manual hoist will be provided for miscellaneous service.

2.2.7 Painting

Interior wood surfaces (not factory treated) will be coated with a fire retardant paint. Interior carbon steel surfaces will be painted.

3.0 Fuel Oil Storage and Distribution System

3.1 Fuel Oil Storage System

The fuel oil storage system will consist of 8 static storage tanks (inflatable type) of 50,000 gal capacity each, 19 ft wide, 72 ft long and 6 ft high when full, and 22 ft wide by 75 ft long when empty. The total storage capacity is 9,520 barrels, providing a 14 months' supply of fuel oil.

They will be distributed in two 24 ft wide by 325 ft long fuel oil storage tunnels located on either side of the main access tunnel. The entire length of the fuel oil storage tunnels will be excavated to approximately 24 ft below existing snow line and the storage tanks placed lengthwise directly on the finished tunnel floor and to one side. The remaining space will be used by unloading and distribution piping, and service aisle. A minimum insulating cover of three feet of snow will be placed on top of the corrugated metal arch tunnel roof.

Lube oil will be delivered to the site by air in drums and placed in the lube oil storage area.

3.2 Fuel Oil Distribution

The fuel oil distribution system is designed for arctic grade diesel fuel oil with a pour point of -80° F.

The fuel oil distribution system will consist of 900 lf of flexible hose pipe connected to two positive displacement pumps placed in separate pits located at the head of each of the fuel oil storage tunnels.

These pumps will be manifolded to the fuel oil piping system and will automatically supply fuel to the day tanks located within the diesel generator building.

3.3 Fuel Oil Unloading - Pole Station

Fuel oil will be delivered to the site by air from McMurdo Sound in 4,000 gal tote tanks of an inflatable type, extra heavy, skid mounted, measuring 7.5 ft wide, 37 ft long and 7 ft high when full. These tanks will be unloaded at the airstrip where two skid mounted gasoline engine driven fuel oil transfer pumps will pump the fuel oil through 1,000 lf of 4 in. flexible hose to the plant's permanent fuel oil storage tanks.

3.4 Fuel Oil Storage - McMurdo Sound

At McMurdo Sound two 5,480 barrel steel storage tanks, 70 ft in diameter and 8 ft high, will be required as temporary fuel oil storage. The tote tanks will be filled from these storage tanks.

4.0 Diesel Generator Plant

4.1 Diesel Generators and Accessories

The plant will include four diesel engine generators, each rated at 250 kw at 600 rpm. The engines will be vertical, inline, single acting, two or four cycle, solid injection, completely enclosed, and full pressure lubricated. Accessories for each engine will include an exhaust gas turbo-charger, exhaust silencer, lube oil pump and cooler, fuel oil booster pump, strainer and filter, floor mounted gauge board, automatic start-stop and synchronizing controls, electric starter, water cooled exhaust manifold, and a structural steel sub-base to support the generator.

The generators will be 312 kva, 4-wire, 0.80 power factor, 3-phase, 60 cycle, 480 v, 600 rpm, with 125 v d-c V-belt connected exciter rated for operation at 9,200 ft elevation. The quality of the power will be consistent with the system requirements.

4.2 Combustion Air System

The diesel engines will draw combustion air from a common plenum through dry impingement type air filters. Relief type louvers will be provided between the plenum and the engine room. Air exhausted from the room at 70° F into the plenum will supply tempered air to the engines.

4.3 Cooling System

A cooling water system common to all units will provide cooling for the operating engines and heating for the idle engines. A circulating pump with a stand-by will circulate water through the system. Heat will be ejected from the engine cooling system to the space heating unit and to an air cooled exchanger.

4.4 Diesel Generator Foundations

The diesel generators will be mounted on steel skid frames by the vendor. Beneath each steel skid frame will be 16 vibration control devices. These in turn will be supported by a heavy timber frame which is separated from the building floor framing. Timber columns will carry the load to a timber mat founded 2 ft below the tunnel floor. After installation of the footings, snow will be backfilled to the level of the tunnel floor. Provision will be made for jacking and shimming the foundation to maintain proper relation to the building floor, and for leveling the frame in the event of unequal settlement.

4.5 Diesel Engine Lubrication System

Each diesel generating unit will have an independent lube oil cooling and circulating system. The circulating pump will be engine driven. A separate operating pump and a stand-by pump will be provided to transfer dirty crankcase oil to a storage tank and clean oil from a storage tank to the crankcases. A centrifuge, complete with transfer pumps, will be provided.

4.6 Instruments

A gauge board will be provided for each diesel generating unit. In addition to the unit controls, instruments will be provided for integrated plant operation of the diesel generating units.

4.7 Plant Piping

Piping for the plant will include the following systems:

- Exhaust piping
- Lube oil
- Fuel oil
- Jacket cooling water

4.8 Starting System

Each engine will be equipped for electric starting from a battery source. The starting system will include an electric starting motor, magnetic and hand starting switches, voltage regulator, and battery charging equipment listed under Section 5.3.

4.9 Auxiliaries Foundations

Auxiliaries equipment will be mounted on the building floor.

5.0 Accessory Electrical Equipment

5.1 Main Switching, Control and Protective Equipment

This equipment will include 480 v switchgear, indoor, metal enclosed, with 25,000 amp interrupting capacity air circuit breakers; and controls, relaying and metering for the generators, exciters and outgoing feeders.

5.2 Auxiliary Electrical Equipment

This equipment will consist of wire, cable and auxiliary equipment associated with the power generating facilities.

5.3 Auxiliary Switching, Control and Protective Equipment

This equipment will consist of one distribution panel board, 480 v, 3-phase, 60 cycle; one 125 v d-c distribution panel, and station battery and battery chargers.

6.0 Miscellaneous Power Plant Equipment

6.1 Fire Extinguishing Equipment

Fire protection equipment will consist of portable, dry chemical extinguishers located throughout the plant.

6.2 Fire Alarm System

The fire alarm system will consist of strategically located signal stations actuating electrically operated sound equipment.

6.3 Plant Air Equipment

The plant air supply will consist of one motor driven, air cooled, tank mounted compressor rated for 10 cfm at 100 psig.

6.4 Shop Equipment

A pump and fuel injector repair room will be provided complete with injector test stand. Shop equipment will include small hand tools and racks for storing miscellaneous spare parts.

6.5 Office Furniture and Equipment

Furniture and equipment for the office area will be provided.

7.0 Transmission Plant

The transmission plant will consist of cable to the access tunnel with necessary supports.

8.0 Communication System

Telephone facilities will be provided.

9.0 Indirect Cost

9.1 General Field Expense

General field expense includes the cost of supervision by the Navy and by contractors' representatives, Navy service personnel, warehousing, warehouse equipment, small tools, consumable supplies, and maintenance of temporary facilities.

9.2 Export Packing and Transportation Costs

9.2.1 Export Packing

Export packing includes the cost of packing and crating sufficient for severe shipping conditions in Antarctic waters and over-the-ice transportation to NAF McMurdo. In addition packages must be finally assembled on sleds or skids for transportation by C-130-B aircraft from McMurdo to Pole Station, and to facilitate unloading at Pole Station and final movement to the construction site. Packing, crating and palletizing will be done preferably at the factory or at Davisville, Rhode Island. However, it is anticipated that some work will have to be done by Navy Construction Battalion personnel after arrival at McMurdo.

9.2.2 Ocean Freight

Ocean freight includes domestic freight forwarding charges, port handling and wharfage charges, and ocean freight from Davisville, Rhode Island to McMurdo Sound. The estimate is based on an estimated cargo of 558 short tons (Table 8), a stowage factor of 1.5, and an estimated unit cost for ocean freight of \$100/mt (Appendix A).

Marine insurance is not included since shipment will be in U. S. Government owned vessels.

9.2.3 Icebreaker Cost

Icebreaker cost is based on an estimated cargo of 558 short tons (Table 8), a stowage factor of 1.5, and an estimated unit cost for icebreaker service of \$76/mt (Appendix B).

9.2.4 Airlift Cost

All personnel, materials and equipment must be flown from NAF McMurdo to Pole Station, and in addition, certain materials and equipment airlifted from New Zealand. The estimate of cost is based on a total of 34 round trip airlifts (Table 8) and an estimated unit airlift cost of \$7,570 per round trip (Appendix C). In addition, the estimate includes an allowance for the ferrying cost (Appendix C) of one cargo aircraft each construction season (Table 8) from the United States and return.

9.3 Start-up and Testing

9.3.1 Shop Testing

Shop testing includes witnessing of the complete testing and operation of the assembled diesel engine power plant by Navy personnel at the manufacturers plant.

9.3.2 Field Start-up and Testing

Field start-up and testing includes all labor, materials, equipment and personnel transportation cost for the initial testing, start-up and regulating of the power plant. Acceptance tests to verify the performance of components and the completed power plant in accordance with the specifications will be performed.

9.4 Contractor's Field Overhead

This item includes an allowance of \$14,000 per man-year for Navy and contractor's personnel for special clothing and transportation of men and supplies. Also included is an allowance for purchasing and expediting, field tests, survey, project photographs and field office supplies.

9.5 Construction Plant

It is assumed that construction personnel will make maximum use of the existing facilities at Pole Station and NAF McMurdo. However, the facilities at Pole Station will have to be augmented with additional temporary housekeeping facilities for some of the construction personnel. It is also assumed that necessary temporary construction buildings such as shops, warehouses, and field offices will be provided.

9.6 Camp Expenses

This includes messing and billeting of contractor's personnel, which will be furnished by the Navy at a cost of \$2.25 per day per man.

9.7 Insurance, Bond, and Financing

Since all field work will be done by Navy personnel, the cost of these items is not included.

9.8 Personnel Mobilization

This includes the pay of Navy construction personnel in the U. S. while in training and in transit to and from the Pole Station.

9.9 Construction Equipment

Costs are included for the Peter Snow Miller, two D-6 tractors, welding generators and miscellaneous tools and equipment required for building and equipment erection.

10.0 Escalation

Escalation is based on an over-all escalation of 6% on labor, equipment and materials.

11.0 Design Engineering

Design engineering costs include the cost of over-all project planning, site layout, concept and detail design of the snow tunnels, buildings, diesel engine generator plant, fuel handling and storage facilities and utilities. Also included is the cost of preparing operating manuals, test procedures and maintenance manuals.

The administrative cost involved in the purchase of equipment is not included.

12.0 Contingency

The contingency is 15% of the cost of the plant including escalation and design engineering.

13.0 Fuel Oil in Storage

Cost of a two-month supply of fuel oil (57,000 gal) is included in the estimate of cost of the power plant. This amount of fuel represents an emergency which would always be on hand.

C. Estimate of Project Cost

SUMMARY

500 KW CONVENTIONAL POWER PLANT

<u>Description</u>	<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
1.0 Land and Land Rights	\$ - -	\$ - -	\$ - -
2.0 Structures and Improvements	49,000	118,000	167,000
3.0 Fuel Oil Storage and Distribution System	41,000	132,000	173,000
4.0 Diesel Generator Plant	32,000	211,000	243,000
5.0 Accessory Electrical Equipment	15,000	70,000	85,000
6.0 Miscellaneous Power Plant Equipment	4,000	12,000	16,000
7.0 Transmission Plant	2,000	2,000	4,000
8.0 Communication System	2,000	2,000	4,000
Total Direct Construction Cost	\$ 145,000	\$ 547,000	\$ 692,000
9.0 Indirect Cost	108,000	1,075,000	1,183,000
Total Construction Cost	\$ 253,000	\$1,622,000	\$1,875,000
10.0 Escalation			115,000
Total Including Escalation			\$1,990,000
11.0 Design Engineering			100,000
Total Estimated Cost Excluding Contingency			\$2,090,000
12.0 Contingency			310,000
Total Including Contingency			\$2,400,000
13.0 Fuel Oil in Storage			180,000
Total Estimated Project Cost			\$2,580,000

ESTIMATE OF CONSTRUCTION COST

500 KW CONVENTIONAL POWER PLANT

<u>Description</u>	<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
1.0 <u>Land and Land Rights</u>	- -	- -	- -
2.0 <u>Structures and Improvements</u>			
.1 General Improvements			
.1.1 Snow Tunnels	\$ 5,000	\$ -	\$ 5,000
.1.2 Tunnel Roofs	8,000	37,000	45,000
.1.3 Water Supply	1,000	2,000	3,000
.1.4 Sanitary Sewage Disposal	1,000	2,000	3,000
.1.5 Tunnel Lighting	3,000	7,000	10,000
.1.6 Fire Extinguishing Equipment (tunnel system and oil storage area)	1,000	2,000	3,000
Sub-Total	\$ 19,000	\$ 50,000	\$ 69,000
.2 Diesel Generator Building			
.2.1 Substructure	\$ 7,000	\$ 3,000	\$ 10,000
.2.2 Superstructure	15,000	50,000	65,000
.2.3 Heating and Ventilation	2,000	6,000	8,000
.2.4 Plumbing	1,000	2,000	3,000
.2.5 Building Electrical	3,000	4,000	7,000
.2.6 Miscellaneous Cranes and Hoists	1,000	1,000	2,000
.2.7 Painting	1,000	2,000	3,000
Sub-Total	\$ 30,000	\$ 68,000	\$ 98,000
Total Structures and Improvements	\$ 49,000	\$ 118,000	\$ 167,000
3.0 <u>Fuel Oil Storage and Distribution System</u>			
.1 Fuel Oil Storage System	\$ 3,000	\$ 62,000	\$ 65,000
.2 Fuel Oil Distribution	3,000	6,000	9,000
.3 Fuel Oil Unloading - Pole Station	2,000	37,000	39,000
.4 Fuel Oil Storage - McMurdo Sound	33,000	27,000	60,000
Total Fuel Oil Storage and Distribution System	\$ 41,000	\$ 132,000	\$ 173,000

ESTIMATE OF CONSTRUCTION COST
500 KW CONVENTIONAL POWER PLANT
(Cont'd)

	<u>Description</u>	<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
4.0	<u>Diesel Generator Plant</u>			
.1	Diesel Generators and Accessories	\$ 18,000	\$ 180,000	\$ 198,000
.2	Combustion Air System	1,000	5,000	6,000
.3	Cooling System	1,000	3,000	4,000
.4	Diesel Generator Foundations	2,000	1,000	3,000
.5	Diesel Engine Lubrication System	1,000	8,000	9,000
.6	Instruments	2,000	4,000	6,000
.7	Plant Piping	5,000	8,000	13,000
.8	Starting System	1,000	1,000	2,000
.9	Auxiliaries Foundations	1,000	1,000	2,000
	Total Diesel Generator Plant	\$ 32,000	\$ 211,000	\$ 243,000
5.0	<u>Accessory Electrical Equipment</u>			
.1	Main Switching, Control and Protective Equipment	\$ 4,000	\$ 35,000	\$ 39,000
.2	Auxiliary Electrical Equipment	4,000	15,000	19,000
.3	Auxiliary Switching, Control and Protective Equipment	7,000	20,000	27,000
	Total Accessory Electrical Equipment	\$ 15,000	\$ 70,000	\$ 85,000
6.0	<u>Miscellaneous Power Plant Equipment</u>			
.1	Fire Extinguishing Equipment	\$ 1,000	\$ 1,000	\$ 2,000
.2	Fire Alarm System	1,000	2,000	3,000
.3	Plant Air Equipment	1,000	3,000	4,000
.4	Shop Equipment	1,000	4,000	5,000
.5	Office Furniture and Equipment	-	2,000	2,000
	Total Miscellaneous Power Plant Equipment	\$ 4,000	\$ 12,000	\$ 16,000
7.0	<u>Transmission Plant</u>	\$ 2,000	\$ 2,000	\$ 4,000
8.0	<u>Communication System</u>	\$ 2,000	\$ 2,000	\$ 4,000
	Total Direct Construction Cost	\$ 145,000	\$ 547,000	\$ 692,000

ESTIMATE OF CONSTRUCTION COST
500 KW CONVENTIONAL POWER PLANT
(Cont'd)

<u>Description</u>	<u>Labor</u>	<u>Permanent Materials and Equipment</u>	<u>Total</u>
9.0 <u>Indirect Cost</u>			
.1 General Field Expense	\$ 47,000	\$ 30,000	\$ 77,000
.2 Export Packing and Transportation Costs			
.2.1 Export Packing	\$ -	\$ 27,000	\$ 27,000
.2.2 Ocean Freight	-	75,000	75,000
.2.3 Icebreaker Cost	-	57,000	57,000
.2.4 Airlift Cost	-	365,000	365,000
Sub-Total	-	\$ 524,000	\$ 524,000
.3 Start-up and Testing			
.3.1 Shop Testing	\$ 5,000	\$ -	\$ 5,000
.3.2 Field Start-up and Testing	12,000	4,000	16,000
Sub-Total	\$ 17,000	\$ 4,000	\$ 21,000
.4 Contractor's Field Overhead	\$ 30,000	\$ 300,000	\$ 330,000
.5 Construction Plant	9,000	30,000	39,000
.6 Camp Expenses	-	2,000	2,000
.7 Insurance, Bond, and Financing	-	-	-
.8 Personnel Mobilization	-	65,000	65,000
.9 Construction Equipment	5,000	120,000	125,000
Total Indirect Cost	\$ 108,000	\$1,075,000	\$1,183,000
TOTAL CONSTRUCTION COST	\$ 253,000	\$1,622,000	\$1,875,000

D. Project Schedule

The project schedule on page 82 for the 500 kw conventional power plant has been prepared to serve as a basis for the estimate of cost. The schedule indicates that design and construction activities span a period of 26 months. Starting of engineering by January 1962, will permit completion and operation of the conventional power plant by February 1964.

Based on the ability of aircraft to fly between NAF McMurdo and Pole Station, the maximum construction season is approximately 90 days. For periods up to one month after the start of the summer season it is not possible to get a vessel into McMurdo Sound due to ice conditions. A construction schedule based on bringing materials, equipment and personnel in by vessel would be limited to a maximum of two months of construction time.

It is assumed that existing facilities at the Pole Station would be enlarged to accommodate the construction crew, and at a later date the operating personnel, prior to the start of construction in 1962-1963 (Ref. 14). The schedule is based on such an expansion of facilities.

The schedules and cost estimates are based on the shipment of all materials from Davisville, Rhode Island, which is the CONUS marshalling point.

The estimated weights of the equipment and material required for construction of the plant are shown on Table 8 in Section III-D for estimated costs and the schedule presented herein.

In addition, the following factors were considered in preparing the schedule and form a further basis for it:

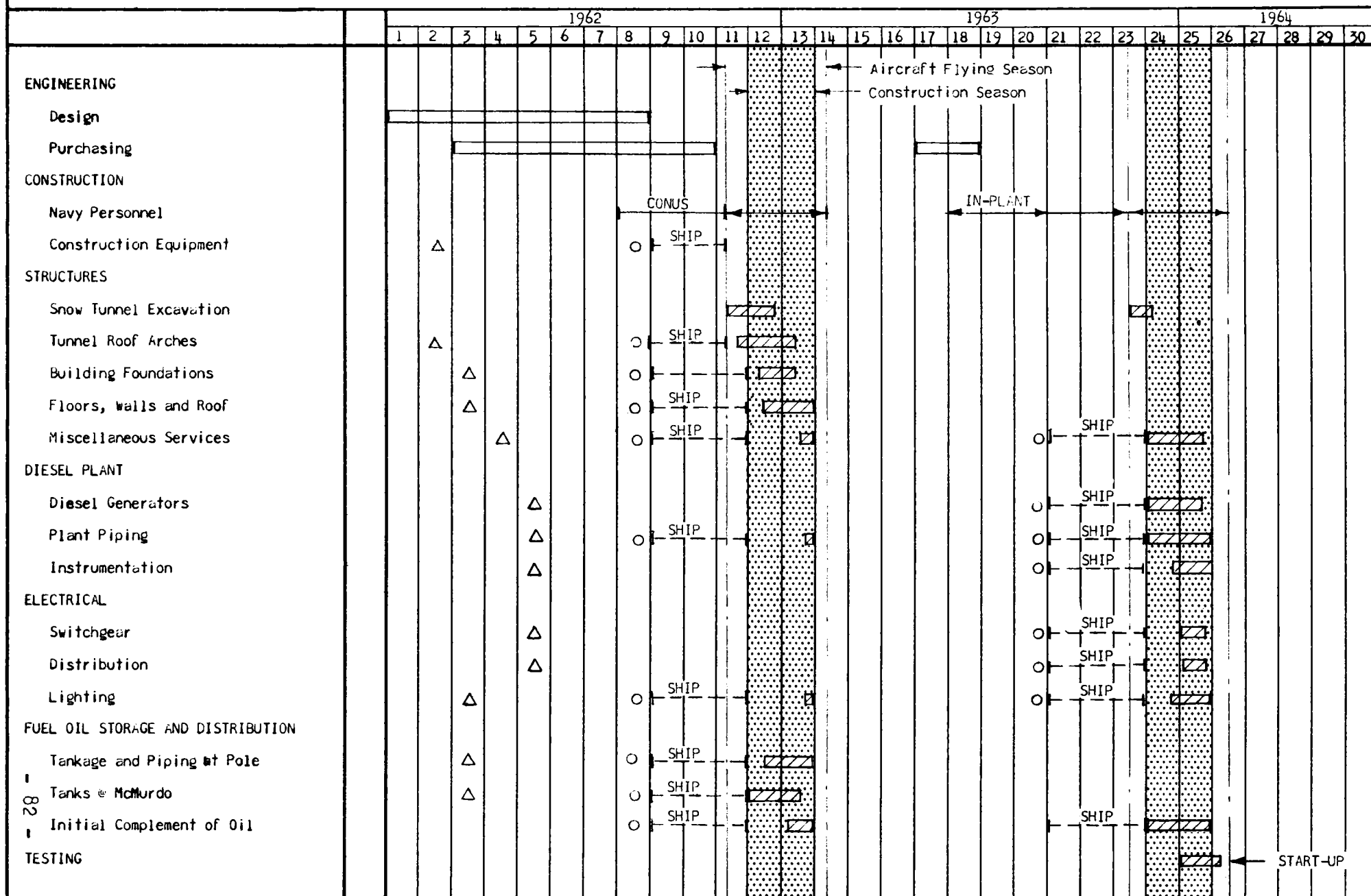
1. Performance of construction work by U. S. Navy Construction Battalion personnel. Billeting and messing facilities will be furnished by the Navy.
2. A period of three months has been allowed for the mobilization and briefing of construction personnel. In addition, supervisory and key construction personnel should spend approximately one month in the diesel-generator subcontractor's plant during the period when the units are being assembled and tested prior to shipment, to familiarize them with the equipment and techniques and problems in assembly.
3. The construction schedule is based on a six-day work week with two 10-hour shifts per day.

4. It has been assumed that construction materials required the first season will be ordered far enough in advance to reach McMurdo Sound by ship not later than December 15, 1962. Shipment of the diesel-generator units the following year will be such as to assure arrival at Pole Station not later than December 15, 1963.
5. The schedule is based on maximum utilization of prefabricated and preassembled units, including mechanical and electrical equipment and piping.

LEGEND

○ FOB Factory
 ▨ Installation
 △ Purchase

PROJECT SCHEDULE
 500 KW CONVENTIONAL POWER PLANT
 POLE STATION



KAISER ENGINEERS
 DIVISION OF HENRY J. KAISER COMPANY

E. Estimate of Unit Power Cost

Unit power costs have been based on a plant operating factor equivalent to 100% of the firm power requirement of 500 kw.

Annual Fixed Charges

Annual fixed charges are based on a 20-year plant life equivalent to 5% of the total project cost. No interest on the investment has been included (Ref. 16).

$$0.05 \times \$2,580,000 = \$129,000$$

Operating and Maintenance Costs

Operating and maintenance labor cost based on an estimated complement of seven military personnel is shown on Table 11, page 85. Labor costs are based on an average annual rate for overseas military personnel of \$20,350, including base pay, transportation of supplies, messing and special clothing as follows (Ref. 10):

Pay	\$ 7,500 per year
Transportation of Supplies	12,250
Messing	400
Special Clothing	<u>200</u>
Total	\$20,350 per man per year

The average annual cost of power plant maintenance materials and operating supplies has been obtained by estimating such costs, excluding cost of major overhauls, at a rate of 1.0 mills per kilowatt hour generated, based on published data of the U. S. Department of Agriculture, Rural Electrification Administration and State of Wisconsin Power Commission. Lubricating oil is also estimated separately because of the high cost of transportation to the Station.

Because the engine generator sets weigh approximately 14 tons, and because of the operating characteristics selected for the engines, i.e., slow speed and low BMEP, it is more economical and less hazardous to perform major overhauls at approximately 25,000 hour intervals than to replace the engines. The estimate of cost therefore is based on a total of 12 major overhauls on the engines during the life of the plant. The estimate also includes allowances for export packing, freight and shipping costs, prorated icebreaker costs for replacement parts, materials, supplies and lubricating oils, and, in addition, a 20% allowance for average escalation of materials and supplies over a 20-year period.

Annual Maintenance Cost

\$0.001 x 4,380,000 kwhr/yr	= \$ 4,400
Shipping cost	= <u>1,500</u>

Sub-Total Annual Maintenance Cost	\$ 5,900
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Lubricating Oil Cost

$\frac{\$3.63/\text{gal} \times 4,380,000 \text{ kwhr/yr}}{3,750 \text{ kwhr/gal}}$	= \$ 4,300
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Major Overhaul Cost

Labor:

12 overhauls x 8 man months each	= 8 man years
8 man years x \$20,350/man year	= \$163,000

Materials:

12 overhauls x \$8,500 each	= <u>102,000</u>
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Total for 20-year period	\$265,000
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Total Average Annual Overhaul Cost	\$13,300
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Tunnel Maintenance Cost

Assume 10% of tunnel construction cost (Ref. 19): 0.10 x \$25,000	= <u>\$ 2,500</u>
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TOTAL MAINTENANCE MATERIALS AND OPERATING SUPPLIES	\$26,000
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TABLE 11
AVERAGE ANNUAL OPERATING AND MAINTENANCE COST

<u>Labor</u>	<u>No. of Personnel</u>	<u>Rate</u>	<u>Annual Cost</u>
<u>Supervision</u>			
Plant Superintendent	1		
<u>Operation</u>			
Power Plant Operators	3		
Auxiliary Operator	1		
<u>Maintenance</u>			
Mechanic	1		
Electrician	<u>1</u>		
Sub-total	7	\$20,350	\$1142,000
Escalation			<u>42,000</u>
Total Operating and Maintenance Labor			\$1184,000
<u>Maintenance Materials and Operating Supplies</u>			\$ 26,000
Escalation			<u>5,000</u>
Total Maintenance Materials and Operating Supplies			\$ 31,000
TOTAL AVERAGE OPERATING AND MAINTENANCE COST			\$215,000

Annual Fuel Costs

The average annual cost of fuel oil for the diesel engine generator plant has been estimated as follows, based on an estimated average unit cost of \$3.87 per gallon for arctic grade diesel oil delivered to fuel storage tanks at Pole Station, and an estimated annual fuel consumption of 340,000 gal as follows:

Annual Fuel Consumption

Annual fuel consumption is based on a fuel rate of 0.55 lb/kwhr of arctic grade diesel fuel (API 34.5° gravity, 7.10 lb/gal) and an average annual power production of 4,380,000 kwhr (operation at 100% of firm power demand of 500 kw).

340,000 gal/yr

Unit Cost of Fuel Oil at Pole Station

Fuel will be transported from the United States in MSTs AOG tankers and transshipped at NAF McMurdo to Pole Station on specially designed 4,000 gal tanks carried by C-130-B aircraft.

Fuel cost f a s CONUS	\$0.12/gal
Ocean freight (Appendix A)	0.33
Icebreaker cost (Appendix B)	0.37
Handling cost at McMurdo (tanker unloading, and filling, handling, and loading of portable tanks for transport to Pole Station)	0.10
Cost of airlift (Appendix C)	
$\frac{\$7,570/\text{round trip}}{4,000 \text{ gal/round trip}}$	1.90
Ferrying cost of cargo aircraft (Appendix C)	
Assuming two aircraft are required to airlift the annual requirement of 340,000 gal	
$\frac{2 \times \$54,000}{340,000 \text{ gal}}$	0.30

Handling cost at Pole Station (includes unloading full tanks from aircraft, filling of station tanks, and reloading empty tanks into aircraft)

0.10

Sub-Total Fuel Oil at Pole Station

\$3.22/gal

Escalation at 20%

0.65

Total Average Cost of Fuel Oil at Pole Station

\$3.87

Annual Fuel Cost

340,000 gal x \$3.87/gal

\$1,316,000

Unit Power Costs

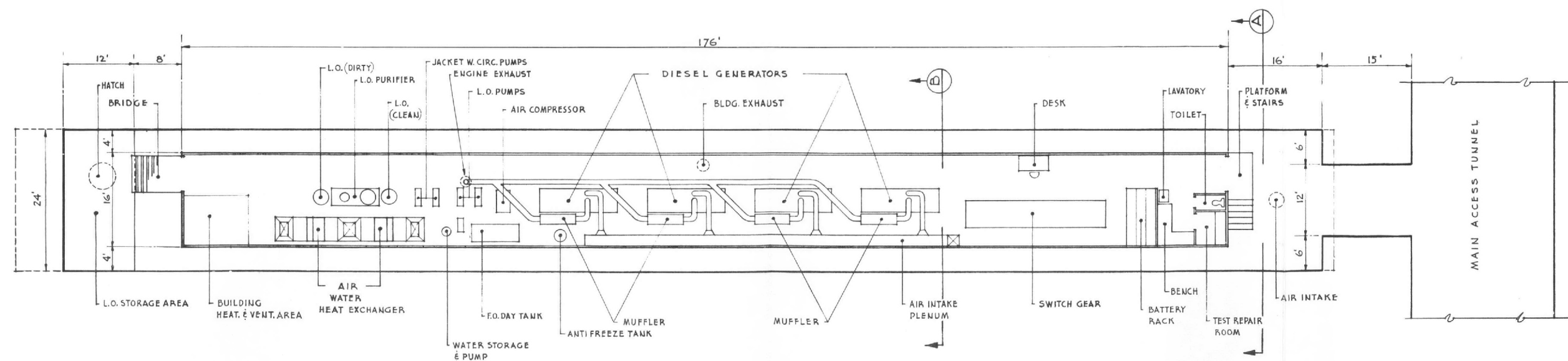
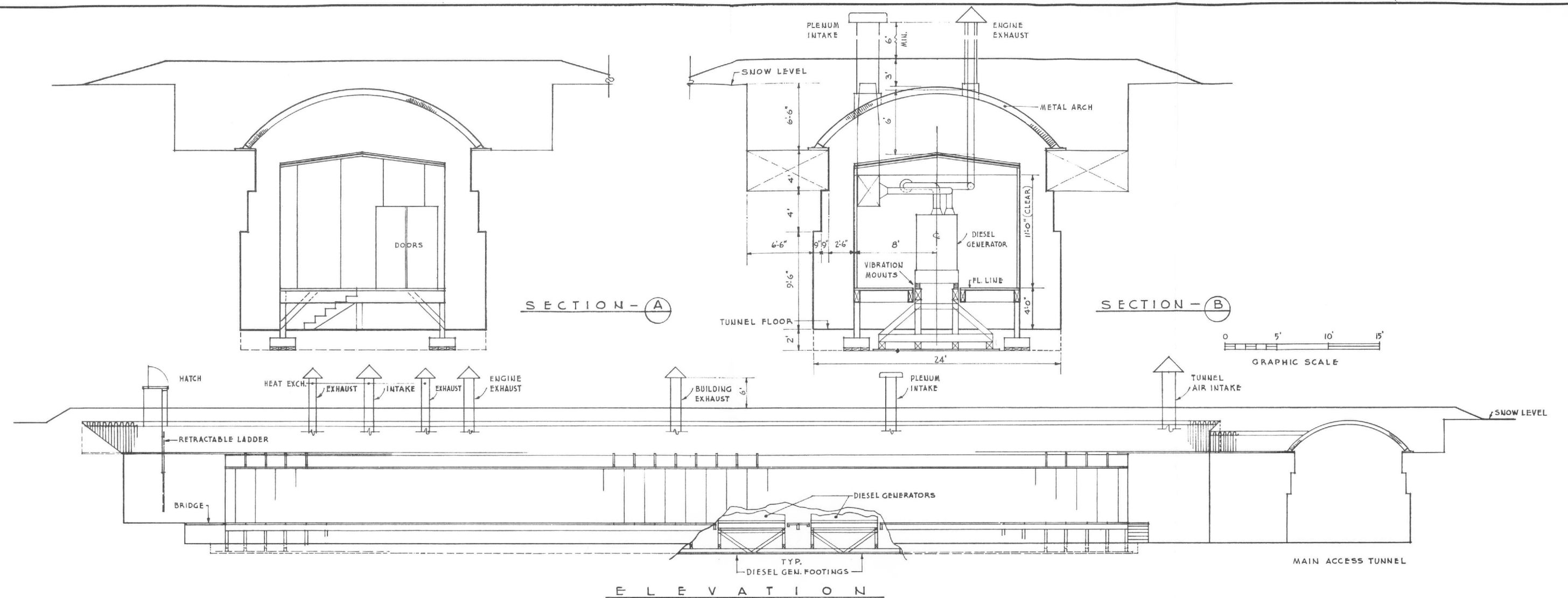
Unit power costs are based on annual power production of 100% of firm power equivalent to 4,380,000 kwhr per year.

	<u>Average Annual Cost</u>	<u>Mills per kwhr</u>
Fixed charges	\$ 129,000	29.5
Operating and Maintenance	215,000	49.1
Fuel cost	<u>1,316,000</u>	<u>300.5</u>
Total	\$1,660,000	379.1

F. Concept Drawings

The following drawings present the conceptual design of the proposed 500 kw conventional power plant.

<u>Drawing No.</u>	<u>Title</u>
1502-C	Plot Plan
1501-G	General Arrangement
1501-E	One Line Diagram



STUDY OF REMOTE MILITARY POWER APPLICATIONS
FOR
U. S. ATOMIC ENERGY COMMISSION

KAISER ENGINEERS

OAKLAND
CALIFORNIA

POLE STATION, ANTARCTICA

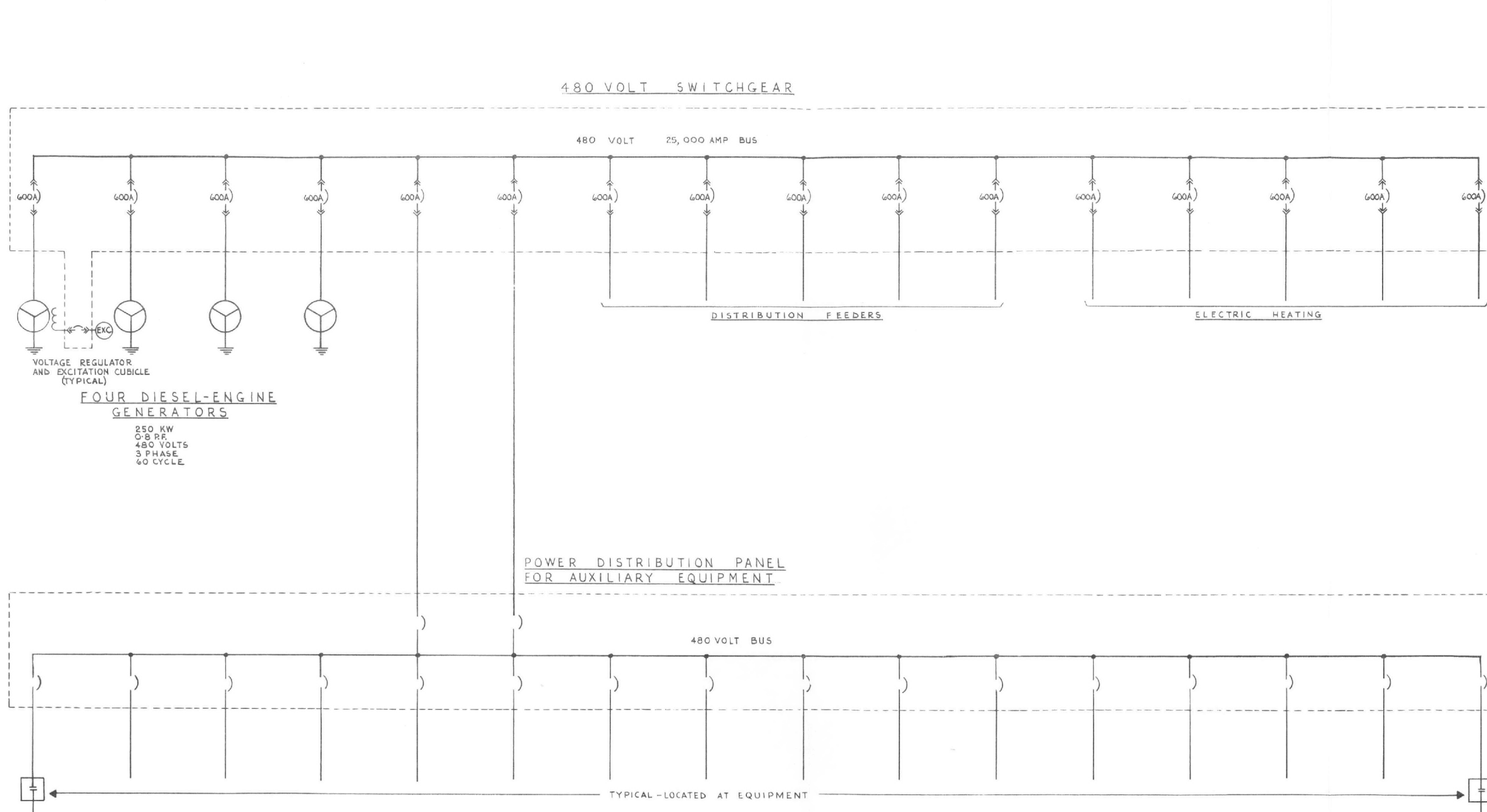
500 KW CONVENTIONAL POWER PLANT
GENERAL ARRANGEMENT

JOB No. 5929

DWG. No. 1501-G

APPROVAL	DATE
PROJECT ENGINEER	5/5/60
CHIEF ENGINEER	5/5/60

SCALE	DATE
DRAWN BY C/W/JACKSON	3/7/60
CHECKED BY R.A. WILSON	4/29/60
APPROVED BY RANSON B. HANSEN	5/5/60
CHIEF DESIGN ENGINEER	5/5/60



STUDY OF REMOTE MILITARY POWER APPLICATIONS FOR U. S. ATOMIC ENERGY COMMISSION			
APPROVAL		DATE	DIVISION OF HENRY J. KAISER KAISER ENGINEERS OAKLAND, CALIFORNIA
SCALE		DATE	POLE STATION, ANTARCTICA
DRAWN BY G. H. HUGHES		4-26-60	500 KW CONVENTIONAL POWER PLANT ONE LINE DIAGRAM
CHECKED BY O. NIEPONICE		4-26-60	
PROJECT ENGINEER <i>W. A. G.</i>	5/5/60	APPROVED <i>W. A. G.</i>	4-26-60
CHIEF ENGINEER		CHIEF DESIGN ENGINEER <i>W. A. G.</i>	5-5-60
JOB No. 5929		DWG. No. 1501-E	

SECTION VI

REFERENCES AND GLOSSARY

A. References

1. Individual Unit Report of Wintering-over Party, Deep Freeze IV, November 1958 to November 1959, dated December 16, 1959.
2. Meeting March 1, 1960, AEC Office, Germantown, Maryland.
3. Letter dated March 21, 1960 from Alco Products, Inc.
4. Letter dated March 3, 1960 from The Martin Co.
5. Letter dated April 5, 1960 from Combustion Engineering, Inc.
6. Letter dated March 4, 1960 from Aerojet-General Nucleonics.
7. Analysis and Report, Prime Power Generation Equipment, Tactical LAR/FAR Sites - Nike-Zeus Weapons System, The Ralph M. Parsons Company, April 1959.
8. "Man's First Winter at the South Pole," by Paul A. Siple, the National Geographic Magazine, April 1958.
9. Meeting, March 16, 1960, Snow, Ice, and Permafrost Research Establishment, Evanston, Illinois.
10. Meeting, March 17, 1960, U. S. AEC, Germantown, Maryland.
11. "ABWR PL-2 Reference Design Report, IDO 19008, CEND-71" Combustion Engineering, Inc., dated January 15, 1960.
12. "ABWR, Core Parameter Study, IDO 19006, CEND-63," Combustion Engineering, Inc., dated December 15, 1959.
13. "PL-2 Design Summary, 1,000 kw Portable Boiling Water Nuclear Power Plant," Combustion Engineering, Inc.
14. "Economic Study of Nuclear Power vs Conventional Power for Antarctica," Department of the Navy, Bureau of Yards and Docks, dated February 1960.
15. Meeting, December 17, 1959, Bureau of Yards and Docks, Washington, D. C.

16. Letter dated September 23, 1959, U. S. AEC, New York Operations Office.
17. Materials/Services and Facilities Available from the United States Atomic Energy Commission, TID 4559 (Rev.), March, 1957.
18. U. S. Federal Register, 22, March 12, 1957, page 1591.
19. Letter dated March 11, 1960, Division of Reactor Development, U. S. AEC, Germantown, Maryland.
20. Economic Study of Nuclear Power, Department of the Navy, Bureau of Yards and Docks, February 1960.

B. Glossary

abs	- absolute
AKA	- Navy attack cargo vessel
amp	- ampere (s)
Ag	- silver
bbl	- barrel (s) - 42 U. S. gallons
BMEP	- brake mean effective pressure
Btu	- British thermal unit (s)
Cd	- cadmium
CONUS	- Continental United States
cfm	- cubic feet per minute
cu ft	- cubic foot (feet)
cu yd	- cubic yard (yards)
d-c	- direct current
diam	- diameter
°F	- degrees Fahrenheit
f a s	- free alongside ship
ft	- foot (feet)
g	- gram (s)
gal	- U. S. gallon (s)
GCRE	- Gas Cooled Reactor Experiment
gpm	- gallons per minute
GTTF	- Gas Turbine Test Facility
hp	- horsepower
hr	- hour
ID	- inside diameter
in.	- inch (es)
In	- indium
kg	- kilogram (s)
kva	- kilovoltampere (s)
kw	- kilowatt (s)
kwhr	- kilowatt hour (s)
kwt	- thermal kilowatt (s)
lb	- pound (s)
lb/hr	- pounds per hour
mph	- miles per hour
MSTS	- Military Sea Transport Service
mt	- measurement ton - 40 cu ft or 2,240 lb
mwt	- thermal megawatt (s)
psf	- pounds per square foot
psi	- pounds per square inch
psia	- pounds per square inch absolute
psig	- pounds per square inch gauge
Pu	- plutonium
rpm	- revolutions per minute
U	- uranium
UF ₆	- uranium hexafluoride
UNH	- uranium nitrate hexahydrate
UO ₂	- uranium oxide
v	- volt (s)
yr	- year (s)

APPENDIX A

OCEAN FREIGHT COST

The cost of ocean freight from Davisville, Rhode Island to McMurdo Sound is based on data (1) prepared by the U. S. Naval Support Force, Antarctica (Task Force 43) for Military Sea Transportation Service Cargo Vessels.

Dry Cargo

Type of ship utilized	AKA
Cargo capacity	6,000 mt
Daily ship charge	\$3,000
Average round trip time	100 days

The unit cost then is:

$$\frac{\$3,000/\text{day} \times 100 \text{ days}}{6,000 \text{ mt}} = \$50/\text{mt}$$

The cost of stevedoring, port handling and wharfage charges in the United States is estimated to be \$10 per measurement ton. No further allowance is made for cost of these items at New Zealand or McMurdo Sound.

The average cost of domestic freight forwarding charges to Davisville, Rhode Island has been estimated to be \$1.40 per measurement ton.

The estimated total average unit cost for shipment of power plant equipment and construction materials to McMurdo Sound is summarized as follows:

Ocean freight	\$ 50/mt
Port handling and wharfage	10/mt
Domestic freight forwarding	40/mt
	<u>\$100/mt</u>

Fuel Oil

Type of ship utilized	AOG
Capacity	1,250,000 gal
Daily ship charge	\$4,100
Average round trip time	100 days

The estimated unit cost of ocean freight for transporting fuel oil from Davisville, Rhode Island to McMurdo Sound is estimated as follows:

$$\frac{\$4,100/\text{day} \times 100 \text{ days}}{1,250,000 \text{ gal}} = \$0.33/\text{gal}$$

- (1) Report: "Economic Study of Nuclear Power vs. Conventional Power for Antarctica," February, 1960, prepared by the Department of the Navy.

APPENDIX B

ICEBREAKER COST

The estimate of icebreaker cost is based on the assumption that one icebreaker will be required for every two cargo ships which enter McMurdo Sound. The average in-service period for icebreakers in Antarctic service is 150 days each year at a daily operating cost of \$6,100 (1).

Dry Cargo

Based on the use of a 6,000 measurement ton capacity cargo ship, the unit cost of icebreaker service for dry cargo shipped into McMurdo Sound is estimated as follows:

$$\frac{\$6,100/\text{day} \times 150 \text{ days} \times 0.5}{6,000 \text{ mt}} = \$76/\text{mt}$$

Fuel Oil

Based on the use of an MSTs AOG tanker of 1,250,000 gal capacity, the unit cost of icebreaker service for fuel oil shipped into McMurdo Sound is estimated as follows:

$$\frac{\$6,100/\text{day} \times 150 \text{ days} \times 0.5}{1,250,000 \text{ gal}} = \$0.37/\text{gal}$$

- (1) Report: "Economic Study of Nuclear Power vs. Conventional Power for Antarctica," February, 1960, prepared by the Department of the Navy.

APPENDIX C

COST OF AIRLIFT FROM McMURDO SOUND

All personnel, materials, and equipment must be flown from NAF McMurdo to the Station. Based on the use of C-130-B aircraft for the airlift, the factors affecting the cost of an airlift are as follows (Appendix D):

Payload	15 short tons (dry cargo)
	4,000 gal (fuel oil)
Average hourly operating cost	\$510
Round trip flying time	7 hours
Fuel cost per round trip	\$4,000

Utilizing the above factors, the unit cost of a round trip airlift (maximum 15 tons) from NAF McMurdo to the Station is estimated as follows:

$$\$4,000 + (7 \text{ hr} \times \$510) = \$7,570/\text{round trip}$$

It is assumed that for each construction season airplanes required for the airlift will be ferried from the United States to NAF McMurdo and returned at the close of the season. Assuming that it takes 73 hours of flying time for the round trip and 66,000 gallons of jet fuel at \$0.25 per gallon, the total cost of one round trip by one aircraft U. S. to NAF McMurdo and return is:

$$\begin{array}{rcl} \$510/\text{hr} \times 73 \text{ hr} & = & \$37,000 \\ \$0.25/\text{gal} \times 66,000 \text{ gal} & = & \underline{17,000} \\ & & \$54,000 \text{ per round trip} \end{array}$$

APPENDIX D

OPERATING CHARACTERISTICS OF THE C-130-B CARGO AIRCRAFT

Data presented is based on an estimated round trip distance of 1,600 nautical miles between NAF McMurdo Sound and Pole Station. Pay load shown is based on the plane carrying sufficient fuel for the round trip plus 3 hours reserve, including an allowance for a 20 knot head wind in each direction.

1. Maximum gross cargo weight for take-off at McMurdo is 30,200 lb. This is predicated on a maximum gross aircraft take-off weight of 135,000 lb, which is limited by ski strength.
2. The maximum load which can be taken off from Pole Station is 40,800 lb gross, based on a 26,100 lb load being taken off at McMurdo. A 30,000 lb load can be taken off from the Pole Station based on a 27,000 lb load being taken off from McMurdo. These figures are based on the provision of a 5,000 ft compacted snow runway at the Stations and the continued operation of engines during the loading and unloading periods.

3. Maximum package size which can be carried in the C-130-B aircraft is as follows:

Height 109 in.

Width with ramp support straps folded down . . . 120.45 in.

Width with ramp support straps in place 115 in.

Maximum length of rectangular package 481.6 in.

The use of timber or snow unloading ramps will be required when loading or unloading packages of maximum length. An approximate 6 in. clearance should be allowed on each side of a package within the maximum widths listed above.

4. The estimated fuel consumption of a C-130-B aircraft based on carrying a full pay load from McMurdo Sound and returning empty is 23,600 lb of J-P-4. The estimated fuel consumption for a round trip is 27,700 lb based on carrying a full pay load to the Station and returning with a full pay load. Based upon an approximate weight of J-P-4 fuel of 6 $\frac{1}{2}$ lb per gallon, these consumption figures above are converted to gallonage figures as follows:

Full pay load from McMurdo and return empty . . 3,600 gal J-P-4

Full pay load from McMurdo and full pay load
return 4,300 gal J-P-4

5. Time required for one round trip is approximately 7 hours.
6. Average hourly operating cost of the plane is \$510, less fuel costs.

